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THE RELATIONSHIP OF DIET TO THE PERFORMANCE OF THE COMBAT SOLDIER. MINIMAL CALORIE INTAKE DURING COMBAT PATROLS IN A HOT HUMID ENVIRONMENT (PANAMA).

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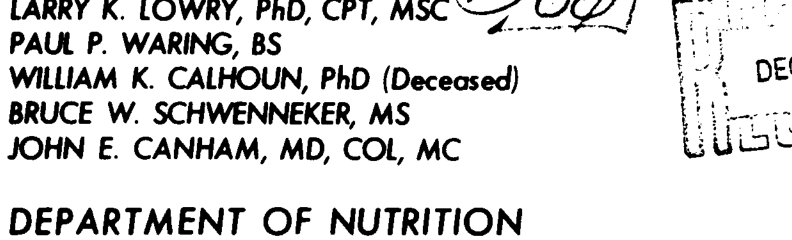

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Human Subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 70-25 on use of volunteers in research.

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The objectives were to determine the nutrient and energy intake necessary to sustain an acceptable level of physiological performance with minimum losses of body nitrogen, minerals and water in soldiers performing simulated combat patrols in a jungle environment. Four groups of heat-acclimated and physically conditioned men consumed 585, 948, 1362, and 3301 kcal/day for 10-day periods while on maneuvers in a Panamanian jungle.

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20. Abstract

Body weight losses were minimal in comparison to previous laboratory studies. The three restricted groups averaged 4.1, 4.7, and 4.2% loss of initial body weight. Changes in biochemical parameters of blood from fasting subjects demonstrated that body hypohydration, though present, was considerably less than reported in previous studies.

Complete nitrogen balances were not determined because of lack of fecal and sweat collections. Nevertheless net body nitrogen losses were observed when daily energy intake was 1362 kcal or less with a daily protein intake of 54.4 g or less. The daily urinary nitrogen losses of the restricted groups gradually decreased during the experimental phase: which suggests some body adaptation to the low caloric and protein intakes.

Data obtained in this study supported our findings from previous studies of short-term starvation and caloric restriction: there were no significant differences in physiological work performance ($\dot{V}_{O_2}$ml/kg/min) on the treadmill when comparing control to caloric restriction periods.

The major portion of the body weight loss appears to be due to the energy deficit as there was subsequent loss of body fat and some water in the three restricted groups. The control group did not show any significant change in body weight or body compartments. Body fat was the primary energy source in the restricted groups, approximately 3% of the total body weight. Hypohydration occurred as plasma and blood volumes and total body waters were significantly decreased.

Skin fold thicknesses were essentially unchanged for all restricted groups. Body waist circumferences showed the greatest decrease which suggests this is the best measurement for evaluating body leanness-fatness under condition of this study. Forearm circumferences showed no significant change.

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PREFACE

We wish to express our sincere gratitude to the many members of the U.S. Army Medical Research and Nutrition Laboratory, especially Robert A. Barnhart, Walter C. Neilsen, Jr., William Wise, Orvile Aker, SFC Lawrence E. Jones, SFC Joseph Taubr, and SFC Douglas Z.B. Wist, for their valuable technical assistance during this study. Our sincere thanks to MAJ Donald Phenix, MSC, for his logistical support and MAJ Harry Greene, MC, LTC Ralph Lazzara, MC, and COL Eugene Eberlin, MC for their medical support during the study.

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The continual support of the field study provided by COL George S. Woodard, Jr., MC, USARSO Surgeon and his Executive Officer, LTC Stephen Hensley, MSC, was extremely helpful and much appreciated by all of the team members.

Our sincere thanks to LTC Hugh Holt, Commander, 3rd Bn, 5th Infantry, and those troops who served as subjects under trying conditions. Without the wholehearted support of these men the study could never have been accomplished successfully.

Our sincere thanks is extended to the many individuals who have given so totally of their time to complete this manuscript. These include: Ms. Kay Robson, Ms. Ann Wilkinson, Mrs. Zweigle, Dr. J.P. Hannon, Ms. Lottie Applewhite, COL Frank Konishi, COL Ronald Johnson, LTC Edwin Kornegay and many others.

It should be noted that due to an inappropriate handling of the data from this study some incorrect conclusions were initially reached. These incorrect conclusions have been quoted in some publications by the first author of this paper and in workshops and in working papers authored by the undersigned. The major error lies in the amount of calories and protein that is necessary to prevent negative nitrogen balances in young adult males expending approximately 3.600 kcal/day. This comment is made to alert personnel who may have come across these references while researching the literature.

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INTRODUCTION

Current trends in warfare situations for the American military services show an increase in the use of highly mobile troops. Since incidents of military conflict can occur in fairly inaccessible areas (jungle-type), they create serious logistical support problems, including resupplying the troops with rations. In many situations, the individual combat soldier must carry not only his pack, weapons, ammunition, and special equipment such as radios and jungle machetes, but also an adequate supply of food and water. The present individual combat ration weighs more than one pound per meal; thus, a 10-day food supply would add more than 30 pounds to his load. Military experience has shown that the combat soldier will discard a great portion of such a large food burden during conditions of stress and survival. Therefore, under such circumstances, the minimal caloric intake required by an individual soldier to perform his duties effectively for short periods of time (up to 10 days) becomes a critical question. For example, would a minimal planned daily ration of 500 kcal, if consumed, be more beneficial to the soldier than the remnants of a 3,600 kcal ration, the majority of which was indiscriminately discarded because of its heavy weight?

The Nutrition Branch, Preventive Medicine Division, Office of The Surgeon General, had received requests from the Department of the Army to specify the minimal daily nutrient and caloric intake necessary to maintain combat soldiers under non-resupply conditions for periods of 0 to 3 days, 0 to 7 days, and 0 to 10 days. Although the soldiers were to be on minimum diet (in weight and calories), they were to have nutrients which would sustain them so they did not show any appreciable loss of efficiency, endurance, combat effectiveness, or sense of well-being. The problem was presented to the Surgeon General's Advisory Committee on Nutrition at a meeting at the U.S. Army Medical Research and Nutrition Laboratory (USAMRNL) in May 1965. After prolonged discussion, it was concluded that there were insufficient data on which to base a reply, and the Advisory Committee strongly recommended that the Laboratory initiate the necessary studies to provide the information. It was further recommended that these studies be conducted with military personnel performing duties under simulated combat conditions. However, before such field efforts could be undertaken, extensive laboratory experimentation was required to identify the physiological and metabolic areas that were most likely to be influenced by short-term undernutrition, and to develop and test experimental procedures which would eventually be used in the field.

The results of the first laboratory study demonstrated that "normal men" could not be expected to remain mentally alert and perform satisfactorily during or subsequent to a 10-day total fast (1-2). In two

1. Consolazio, C.F. et al. Am J Clin Nutr 20:672, 1967.
2. Consolazio, C.F. et al. Am J Clin Nutr 20:684, 1967.

later studies (3-5) the effects of caloric restriction, rather than total fasting, were investigated. Eight "normal" subjects were used in both instances, with one-half of each group receiving mineral supplementation. In one of these studies (3), the diet consisted of 420 carbohydrate per day for a 10-day period with energy expenditure being maintained at approximately 3200 kcal/day. It was anticipated (6) that these subjects would have minimal dehydration, minimal protein catabolism and would exhibit neither ketosis nor unacceptable loss of mental and physical performance. The results of this study (4) indicated that although ketosis was prevented, the 420 kcal from carbohydrate alone did not prevent hypohydration or protein catabolism. However, when the 420 kcal of carbohydrate was supplemented with minerals, body water and body weight losses were reduced; the average body weight loss during the 10 days was 560 g/day for the unsupplemented and 410 g/day for mineral-supplemented subjects.

Since nitrogen losses (4) were high in both the supplemented and unsupplemented subjects, 6.1 and 6.2 g/day, a subsequent study (5) was conducted in an attempt to reduce protein catabolism and to minimize hypohydration, mineral losses, and decrements in mental and physical performance. The 8 male volunteers received 500 kcal/day for 10 days. The diet consisted of 40 g of protein and 85 g of carbohydrate. Four of the 8 men received a daily mineral supplement. The energy expenditure was increased to 3600 kcal/day in efforts to simulate patrol activities. The unsupplemented group showed greater body weight loss and hypohydration than the supplemented group during the 10-day period. Both groups showed considerable protein catabolism and some ketosis, probably because of the fairly high rate of energy expenditure. Although work capacity, as measured on a treadmill, was essentially unchanged in both groups, the mineral-supplemented group appeared to be in better physical condition: body hypohydaration of this group was minimal during the energy restriction period.

OBJECTIVES AND MILITARY JUSTIFICATION

The objectives of the field study reported in this document were: (a) to determine the minimal energy intake that would prevent unacceptable losses of mental and physical performance of men on maneuvers and (b) to obtain some measure of any decrement in performance after periods (up to 10 days) of reduced energy and other nutrient intakes. Studies of soldiers performing strenuous training maneuvers would provide data that were more applicable for making recommendations concerning the minimal nutrient and caloric intakes compatible with acceptable combat effectiveness. Furthermore, any measurable decrements in performance would provide additional information to officers who would be planning similar maneuvers in combat situations.

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3. Consolazio, C.F. et al. Am J Clin Nutr 21:793, 1968.
4. Consolazio, C.F. et al. Am J Clin Nutr 21:803, 1968.
5. Johnson, H.L. et al. Am J Clin Nutr 24:913, 1971.
6. Gamble, J.L. Proc Am Philos Soc 88:151, 1944.

MATERIALS AND METHODS

The study was conducted in a relatively isolated jungle environment in the Canal Zone, Panama, September-October 1968, during the rainy season which offered fairly adverse weather conditions. Measurements of daily high and low ambient temperatures, Wet Bulb Globe Temperature (WBGT) Index and precipitation were made throughout the day in the bivouac area by members of the local meterological team.

One hundred twenty heat-acclimated soldier volunteers were selected for the test. All were from the same company and had spent at least 3 months in the Canal Zone under conditions of fairly intensive training. A health record review, a medical history and a physical examination were obtained on each subject before the study began. Each man had a pre-training electrocardiogram (ECG), and men from the lowest caloric intake group had electroencephalograms (EEG) taken during the control and restriction periods of the study. The EEGs were kindly obtained and initially interpreted by the Chief of Neurology, Gorgas General Hospital, Canal Zone. The 120 men were randomly divided into six groups of twenty men each. This report will concentrate on the studies performed on Groups I through IV. This is to note that after a suitable control period Group V and Group VI were fed the Meal, Combat, Individual and the Long Range Patrol Packet respectively for 26 days. Groups V and VI were on a separate study and findings from that study were to be reported by the Biochemistry Division, Dept. of Nutrition. For Groups I - IV, the study was divided into three phases: (a) a control period to obtain baseline data, (b) a 10-day experimental period with various levels of food intake, and (c) a rehabilitation period of 8 days to evaluate the return to normal. During the control and rehabilitation periods, all of the subjects received a normal, garrison-type ration providing approximately 3500 kcal/day. Ten men from each of the first four groups were studied intensively for maximal work performance and body composition changes. The four groups were fed different diets for the 10-day experimental period.

Group I: Diet consisted of 600 kcal/day (40 g of protein and 110 g of carbohydrate).* Each ration module contained 200 kcal; each man received three modules per day.

Group II: Diet consisted of 1000 kcal/day (40 g of protein and 210 g of carbohydrate).+ Each module unit contained 250 kcal: each man received four units per day.

Group III: Diet consisted of 1500 kcal/day (60 g of protein and 315 g of carbohydrate).+ Each module was the same as given to Group II (250 kcal); each man in the group was given six units per day.

Group IV: The diet provided 3500 kcal/day in the form of a garrison-type ration (normal foods) containing 13% protein, 40% fat, and 47% carbohydrate. This diet was fed ad libitum to the group for the entire study.

To distribute the daily workload for the investigators throughout the week, groups were staggered by one day for the various measurements so that each group was evaluated for work capacity and body composition on the same corresponding day of the restriction period.

Body weights. Throughout the study nude body weights were taken each morning after voiding.

Urine. Complete 24-hour urine collections were obtained daily from each man. After measurement of the total volume, pH, specific gravity, and qualitative tests for sugar, albumin and acetone, the urines were preserved at pH 2.0 and refrigerated for subsequent analyses. Samples were analyzed at USAMRNL for total nitrogen, urea nitrogen, uric acid, creatinine, sodium, potassium, calcium and magnesium.

Blood. Fasting blood samples were taken during each of the three phases. After analyses of hemoglobin and hematocrit, the blood was centrifuged and plasma was separated and frozen for further analyses of glucose, total protein, free fatty acids, urea and uric acid, osmolality and minerals, including sodium, potassium, calcium, and magnesium.

Feces. The collection of fecal material was impractical in the jungle environment without sufficient refrigeration, therefore, measurement of fecal nutrients were not attempted.

Sweat. One-hour sweat and urine samples were collected from each man during the control period, on Days 4 and 10 of restriction, and during Day 7 of rehabilitation. The total sweat loss was calculated as the difference between the initial and final body weight since oral intake or urinary and fecal excretion were not permitted between weighings (7).

The sodium, potassium, calcium, and magnesium concentrations in the food, sweat, and urine samples were determined using the atomic absorption spectrophotometer (Perkin Elmer Corporation, Norwalk, Conn. 06856).

Work Performance. Physical activity consisted of various military training exercises and jungle maneuvers.

Maximal work performance was measured during the control period, on Days 3 and 9 of the restriction period and on Day 6 of rehabilitation. The maximal work performance test consisted of walking on the treadmill at 3.4 mph on the level, and increasing the grade by 1%

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* The restricted diet modules for Group I contained milk powder, sugar and dried fruit.

+ Groups II and III had the same items as Group I with milk pudding mixes added.

7. Consolazio, C.F. et al. J Nutr 79:399, 1963.

each succeeding minute until the person stopped because of exhaustion (8). Oxygen uptakes, pulmonary ventilation and heart rates were measured continuously during the entire exercise test (9). In addition, total work time and recovery pulses (from 1 to 1.5, 2 to 2.5, and 4 to 4.5 minutes of recovery) were recorded for calculating the physical fitness index (PFI) scores. The PFI is weighted heavily by the duration of the exhausting exercise (10).

The second performance test consisted of a timed 15-mile contest march (or run) conducted once during the control period and on Day 10 of the experimental period. Such forced marches served two purposes: (a) they required prolonged energy output with resulting physical stress, and (b) they provide an estimate of physical performance, including endurance.

Pulmonary Function. Lung compartment measurements included vital capacity, maximal breathing capacity and total lung capacity. They were taken at various intervals throughout the study.

Body Compartments. The body compartment measurements were made during the control period, on Days 4 and 10 of the experimental phase, and on Day 7 of rehabilitation. Body density was computed from body volume as measured by the direct water displacement technique of Allen et al. (11), and corrected for the residual lung volume by the modified nitrogen washout technique of Rahn et al. (12).

Blood volume determinations were made by infusion of Evans Blue Dye (T-1824) as reported by Constable (13). Extracellular water was determined by measuring thiocynate space (14). Total body water was determined by the deuterium oxide dilution (100 g ingested) technique by measuring urine and serum levels between a 3 and 5 hour equilibrium period (15).

Selected anthropometric measurements were made, including circumference of the biceps, waist, buttocks, chest, as well as the arm and scapula skinfold thicknesses as designated by the Committee on Nutritional Anthropometry (16).

8. Balke, B. Report No. 1, Program No. 21-32-004, USAF Sch Aviat Med, 1952.
9. Nelson, R.A. et al. Report No. 318, USAMRNL, May 1968.
10. Consolazio, C.F. et al. *Physiological Measurements on Metabolic Function in Man.* McGraw-Hill, 1963.
11. Allen, T.H. et al. Report No. 250, USAMRNL, September 1960.
12. Rahn, H. et al. J Appl Physiol 1:725, 1948.
13. Constable, B.J. Clin Sci 17:597, 1958.
14. Tomaszewski, L. Clin Chim Acta 16:417, 1967.
15. Nielsen, E.C. et al. J Appl Physiol 31:957, 1971.
16. Committee on Nutritional Anthropometry, Nat Acad Sci, NRC Human Biol 28:111, 1956.

Statistical Evaluation. All data were analyzed statistically by analysis of variance (17). The Neuman-Keuls tests were used to evaluate differences between means. Differences at the 5% probability level were considered significant.

RESULTS

Weather Measurements. The daily high ambient temperatures ranged from 85.6 to 92.6F throughout the study. The total percipitation during the calorie restriction experimental period was 5.22 inches, or an average of 0.52 in/day. This resulted in a fairly high maximal WBGT comfort index that averaged 88.7 F during the entire calorie restriction period. In 17 out of 24 days, the maximal WBGT index was above 88 F (Fig. 1). During the 10-day experimental period relative humidities averaged 92.6, 71.3, and 84% at 0800, 1200 and 1600 hours daily.

Body Weight Changes. Body weight changes are shown in Tables 1A and 1B. Table 1A describe changes that occurred in all subjects who finished the study. Table 1B describes the changes for those subjects who were intensively studied. Table 1B reveals losses averaging -2.56, 3.69 and 2.92 kg/man for Groups I, II and III, respectively during the experimental period. These losses represented 3.6, 5.0 and 3.7% of the control body weight. Group IV personnel lost 0.04 kg/man during the same period of time.

Nutrient Intakes. Daily energy intakes averaged 585, 948, 1362 and 3301 kcal/day for Groups I to IV, respectively (Table 2). The average intake of the other macronutrients, and of some vitamins and minerals are presented in this table.

Volume and Characterization of the Urine. The daily 24-hour volumes were not significantly different in Groups I, II and IV. However, the values for Group III were significantly decreased from 1234 to 852 g/day during restriction (Table 3).

The mean urinary specific gravity remained essentially unchanged for Groups I, III and IV; however, the Group II values were significantly decreased during the restriction period. The daily urinary pHs and total solids in the daily urines were essentially unchanged for all groups.

During the first 6 days of the experimental period, 28.3% of Group I, 9.1% of Group II, and 12.5% of Group III showed positive tests for ketone bodies in the urine, whereas only 2.5% of the control Group IV showed the same positive reactions. Two men from Group I showed consistent ketone bodies in the urine. Subject 1 showed a positive reaction for the first 6 days, and subject 13 showed a positive reaction for all of the 10 days of restriction.

17. Winer, B.J. Statistical Principles in Experimental Design, 2nd edition. McGraw-Hill, 1971.

Intake and Urinary Excretion of Nitrogen and Minerals. Nitrogen excretion was similar for Groups I, II and III and less than Group IV (Table 4). Groups I, II and III were in negative nitrogen balance during the experimental period.

Urinary nitrogen excretion (Table 21) gradually decreased during restriction for Groups I, II and III. Group I values decreased from 11.1 to 5.3 g/day, Group II from 13.5 to 5.4 g/day, and Group III from 15.0 to 7.1 g/day during the last day of restriction. The nitrogen excretions for Group IV were essentially unchanged throughout the study. While the average daily total nitrogen losses during the experimental period for Groups I, II, and III were not statistically different between groups, all of these groups were significantly different from Group IV. Urea nitrogen values also significantly decreased during restriction for Groups I, II and III, averaging 6.0, 5.3 and 5.8 g/day. As expected Group IV values were essentially unchanged (average, 9.8 g/day) during the experimental period. The urinary excretions of uric acid were significantly decreased in Group II (average, 247 mg/day) and Group III (average, 233 mg/day) during the experimental period. Creatinine excretions were significantly decreased for Group II (average, 1.35 g/day) and for Group III (average 1.47 g/day).

The urinary excretion of sodium during the experimental period (Table 4) was significantly decreased for the three restricted groups. This reflected the decreased dietary intake. However, the decrease in urinary output was not sufficient to prevent negative balances. Group I decreased from a control value of 2.93 to 1.40 g/day; Group II from 3.23 to 1.25 g/day; Group III from 4.01 to 1.62 g/day. As expected Group IV values were not significantly different throughout the entire study. All groups including IV were in negative potassium balance with the largest negative balance in Group II. Calcium intake and urinary excretion was similar for all groups. Only Group III had a significant decrease in urinary magnesium.

Fecal and sweat losses were not available for complete balances. Even without these losses Groups I, II and III showed negative balances for total nitrogen, sodium and potassium. The addition of fecal and sweat losses would make them more negative. Group III had a marginal negative nitrogen difference of 0.37 g/day. However, the addition of fecal and sweat losses would result in a more negative balance. Calcium and magnesium differences were positive and the inclusion of sweat and fecal losses probably would not have changed the positive nature of the difference.

Biochemical Paramenters, Blood

Hemoglobin (Table 5). Group IV consistently had the lowest means and Group II, the highest. Significant group differences are indicated. By two way analysis of variance (2xANOVA) day effect was significant with all groups highest on the first restriction measurement and Groups II to IV decreased on the next measurement.

Hematocrit. Again, Group IV had consistently the lowest means and Group II, the highest. Significant "between group" differences are indicated in Table 5. Mean values decrease for all restriction groups during the experimental period. By 2xANOVA these changes, over time, were significant.

Blood Urea Nitrogen (BUN). During the control and rehabilitation period the BUN values for Group I were significantly lower than the other groups (Table 5). Over time Group I demonstrated the most significant changes. By 2xANOVA there were significant changes over time with the mean values of the restriction groups decreasing during the experimental period and returning to normal during rehabilitation. The control group (Group IV) had no significant change and only minimal absolute change over time.

Glucose and Free Fatty Acids (FFA). As can be noted in Table 5 (glucose) and Table 6 (FFA) there were no biologically significant changes in these two biochemical parameters.

Total Protein. Significant between group differences existed (Table 6) with Group II having the highest and Group III the lowest means. By 2xANOVA the day effect was significant for all four measurements and for the control vs rehabilitation but not during restriction due to the increase in the values of the control group while the means of the restricted groups decreased. There was significant day X group interactions for the four measurements ($P<0.001$) and during restriction ($P<0.005$) mostly due to control group changing in opposition to the restricted groups.

Serum Osmolality (Table 6). There were significant group differences for the individual measurements and for 4 measurements ($P<0.002$), 2 restriction measurements ($P<0.001$) and control-rehabilitation measurements ($P<0.003$). Group I was consistently lower than the other groups except for day 10 of the experimental period. There were significant day effects for all four measurements ($P<0.002$); during restriction ($P<0.002$) and the control vs rehabilitation because all groups decreased throughout the study except Group II which reached the lowest mean value of the entire study on the 10th day of restriction and then increased during rehabilitation.

Serum Sodium (Table 7). By Students t test there were minimal significant changes for serum sodium but with 2xANOVA significant day effects were noted when all four measurements ($P<0.006$) and the two restriction measurements ($P<0.027$) were compared. This was due to the increase for all groups at time of the first experimental period measurement. The elevation persisted for Groups I, II and IV during the second experimental period measurement. The three restricted groups had returned to control values during rehabilitation.

Serum Potassium (Table 7). There was a significant day effect for the four measurements ($P<0.007$) due to the consistent but slight increase for three of the four groups across time with no change for Group II.

Serum Calcium (Table 7). There were significant group differences ($P<0.009$ for four measurements) with Group II consistently the highest and Group III mean values generally the lowest. A significant ($P<0.004$) day effect was noted on comparison of the control-rehabilitation measurements.

Serum Magnesium (Table 7). Significant group differences were noted during the control and rehabilitation periods due to the low mean values for Group I.

One Hour Sweat and Urine Collections. The one-hour sweat rates were generally increased during the experimental period for Groups I, II and III (Table 8). The greatest increase occurred in Group II. However, the sweat rates for Group IV were significantly reduced for the same period. The one-hour urine volumes were significantly reduced at Day 10 of the experimental period for Group I and II. The urine volumes for Groups III and IV were essentially unchanged.

Urinary sodium excretions per hour and the concentrations of sodium in the urines were significantly reduced during the restriction period (Table 9). By 2xANOVA there were significant differences between the groups during the experimental phase with the sodium losses directly proportional to the caloric intake. The changes over time for the restricted groups were significant. The sodium sweat concentration and sodium excretion appeared to be unchanged during the experimental period for Groups I and IV, and were variably changed for Groups II and III during the study. The amounts of potassium excreted in one-hour sweat sample were increased in Groups I, II and IV during the experimental period (Table 10). The urinary concentrations of potassium increased throughout the experimental period and return to below control values upon rehabilitation. The urinary concentration of potassium also was increased for the control group.

The total hourly excretion of calcium in sweat was fairly constant for all groups ranging between 29 and 57 mg/hr (Table 11). The concentration of calcium were decreased for the restricted groups during the experimental period. The urinary calcium concentrations appeared to be unaffected by the dietary intake and the same also was true for the hourly excretion of calcium in the urine.

The magnesium intakes during the experimental period ranged between 112 and 476 mg/day for the various groups (Table 4). The intake recommended by the National Research Council (18) is 350 mg/day. The concentration of magnesium in sweat did not vary greatly within any of the groups during the study (Table 12). The urinary concentration of

18. National Academy of Sciences, NRC. Recommended Dietary Allowances, 8th rev ed, 1974.

magnesium was significantly increased in Groups I and II during the experimental period. In the control group, the urinary concentration of magnesium remained relatively stable. The amounts of magnesium found in the one-hour urine specimens were comparable to the amounts found in the sweat samples.

Body Compartments/Body Composition

Blood & Plasma Volume. Significant group differences existed for total blood volumes. Group I's mean blood volume was consistently less than Groups III's and IV's and during rehabilitation was less than the three other groups (Table 13). The blood volumes were significantly decreased for Groups I and III by Day 4 of restriction. However, on Day 10 of restriction Groups I, II and IV were not significantly different from the control values. The blood volume for Group IV was essentially unchanged during the entire study. During rehabilitation, the blood volumes approximated the control values.

The mean plasma volume for Group I was significantly decreased during Day 4 of restriction, but the value at Day 10 was not significantly different from that of the control period. The plasma volumes for Group III and IV were essentially unchanged during the experimental period. Throughout the study the mean plasma volume for Group I was significantly less than those for Groups III and IV. During rehabilitation, all plasma volume values were essentially unchanged from control values. The red cell volumes calculated by difference indicated a decrease for all groups during the experimental period. Group I values were reduced from 2521 to 2169 ml, Group II from 3054 to 2657 ml, Group III from 2937 to 2474 ml and Group IV from 2689 to 2518 ml.

Extracellular Water. Extracellular waters determined by thiocyanate dilution demonstrated no intergroup differences during the study. The values for Group IV were significantly increased during the experimental and rehabilitation periods. Group IV values were increased from 16.04 to 19.05 kg (Table 14). By 2xANOVA there was a significant day effect during the experimental period with increase by all groups.

Total Body Water (Deuterium Dilution). Total body water determined by deuterium dilution did not demonstrate any differences between groups (Table 15). By 2xANOVA there was a significant ($P<0.001$) decrease of the total body water of the dietary restricted groups with time. The most significant decreases occurred during the experimental period with the greatest percent decrease reflected at time of the first experimental period measurement. During rehabilitation the values for Groups II and III increased but the values of the restricted groups during rehabilitation were still significantly ($P<0.002$) depressed as compared to the control period. Total body water determined by deuterium oxide dilution is expressed as the percent of total body weight in Table 16. The higher percent body fat of Group III is reflected in the consistently lower percent body water of this group when compared to the other groups.

Estimated Compartments. As noted, body density was determined by use of a body volumeter. Based upon body weight, body density and previously derived formula body fat was estimated and lean body mass derived by difference. Total body water, total protein and body mineral were further derived by use of fixed percentage factors from the lean body mass and are presented in Table 17. Group III consistently had more fat than the other groups with these differences significant when compared to Group II and IV. No intergroup differences existed for protein, minerals or body water. By 2xANOVA there were significant differences across time for body fat with all groups decreasing during the experimental period ($P \sim 0.000$). While Group III regained fat during the rehabilitation period the other three groups losses were sufficient to maintain the significance across the entire study. Maximal fat loss represented 18.5, 20.7, 13.0, and 12.5% of initial body fat for Groups I, II, III, IV respectively but by the time of measurement in the rehabilitation period Group III had decreased its loss to 9.2% of its initial body fat weight.

There was a significant decrease (by 2xANOVA) in total protein when the first experimental period measurement for the restricted groups was compared to the control period and there was a significant increase ($P<0.001$) when the rehabilitation period values were compared to those from the control period despite the slight decrease for Group III. By 2xANOVA the total body water decreases observed for the restricted groups between control and the first experimental measurement were significant as were the increases between the first and second experimental period measurements. The body minerals reflected similar changes noted for body proteins.

In Table 18 we have presented the lean body mass derived by densitometry and lean body mass and total body water derived from densitometry as expressed as a percent of body weight. There are no intergroup difference for lean body mass but the relative fatness of Group III does produce significant differences when lean body mass and total body water are expressed as a percent of body weight. Changes over time reflect the change in body weight and body fat.

Anthropometry

Skinfolds. The changes in the triceps and scapula skinfold measurements were minimal and probably of little biological importance except for the decrease across time of the skinfold measurements for Group III (Table 19).

Circumferences. The circumference of the biceps and of the trunk at the level of the xiphoid process, the waist and the buttocks are presented in Table 20. The changes in the circumferences of the forearms and calfs were quite similar to the biceps and have been omitted. Intergroup differences largely reflecting the relative fatness of Group III are noted. The trunk measurements significantly reflected the

dietary restriction imposed on Groups I, II and III during the experimental period (2xANOVA). These reductions tended to persist for Group III during the rehabilitation period while Groups I and II returned towards control values.

The percentage changes for the circumferences and skinfold thicknesses are summarized in Table 21. Changes for Group III were consistent while those for the other groups were variable. In general the trunk circumferences tended to reflect the weight changes observed in Table 1B.

Pulmonary Function. Pulmonary function measurements were done on each subject during the control period, twice during the experimental period, and once during the rehabilitation phase using a Collins 13-liter spirometer. The measurements included maximal breathing capacity (MBC), MBC frequency (respirations (R)/min), vital capacity (VC), expiratory reserve volume (ERV), inspiratory capacity (IC), total lung capacity (TLC), reserve volume (RV) and the reserve volume/total capacity ratios (RV/TC). Considerable intergroup difference existed throughout the study (Tables 22 and 23) particularly for MBC, MBC frequency, VC and IC.

Maximal breathing capacities were essentially unchanged for the three restricted groups: they ranged from 152 to 165 liters for Group I: 173 to 186 liters for Group II: and 188 to 194 liters for Group III (Table 22). The control group MBCs were also essentially unchanged. The MBC frequency (R/min) data were significantly increased only in Group III during the rehabilitation period. The vital capacities were essentially unchanged for Groups I, II and III during the experimental period. By 2xANOVA the rehabilitation values were significantly decreased from the control period. The expiratory residual volumes (ERVs) demonstrated a significant change over time ($P<0.037$) reflecting the increase during the experimental period of the three restricted dietary groups with return towards control values during rehabilitation (Table 23).

The inspiratory capacities showed significant differences between the groups because of the low values for Group I. The mean residual lung volumes, determined by nitrogen washout, showed variation but there were almost no significant differences observed (Group I differed from Group II during rehabilitation). Total lung capacities were not changed over time but Group I did differ from Group IV on the first measurement during restriction. The RV/TC ratios for Group I were consistently higher than those of the other groups. There was no change of the RV/TC with time. The percentage changes in the lung compartments as assessed by pulmonary function tests are presented in Table 24.

Electroencepholographic Findings. The results of the EEGs from the ten men in Group I who were studied intensively appear in Appendix C.

Physical Performance. The maximal treadmill work times for all groups were not significantly different from control values and not significantly different from each other (Fig. 2). Maximal heart rates were essentially unchanged during the entire study for the four groups. The heart rates averaged over 186 beats/min for all groups. With the exception of Group IV, all rehabilitation values were similar to the controls. Although the maximal work times were similar during restriction for Groups I, II and III, the recovery heart rates after maximal work were significantly decreased for Groups I and IV during restriction.

Maximal oxygen uptakes in liters/min and ml/kg/min for the four groups during the experimental phases were measured. Average values in liters/min for Group I and III were significantly reduced during the restriction period. Groups II and IV values remained essentially unchanged. Oxygen uptakes in ml/kg/min for Group I were significantly different during the rehabilitation period from values obtained in the control period. However, Group III values remained significantly decreased during the restriction period. Group II and IV values were essentially unchanged from control periods when calculated in ml/kg/min.

A second assessment of performance, a forced 15-mile march, was done on the ten men from each group who were not studied extensively. In general, there were no significant differences between the four groups (Fig. 2), and no significant differences between controls and the restriction periods (except Group III). The men averaged less than 220 min for the timed course. The best time for the distance was 156 min.

DISCUSSION

This study was the fourth in a series conducted by us on the effects of short-term caloric restriction (up to 10 days) on physical performance and selected body changes. Since previous studies suggested that the minimal daily intake should contain at least 600 kcal (3) with 110 g of carbohydrate and 40 g of protein, it was anticipated that the additional carbohydrate consumed in this study should completely prevent ketosis. While previous laboratory studies were adequate for preliminary observations, the study of the physiological effects of reduced calorie intakes required a more realistic environment. Troops performing strenuous training maneuvers in a jungle environment provided the logical situation. Data concerning any changes in performance could provide valuable information to officers in the planning and execution of maneuvers in combat situations.

The daily military activities were carried out in spite of severe environmental conditions. The rainfall and high humidities resulted in high maximal daily WBGT that were in uncomfortable ranges, e.g., between 88 and 90 F during 17 out of 24 days. The U.S. Army (19) normally recommends only limited physical activity by hardened, acclimated

troops under these adverse conditions. The presence of some ketonuria in Group I during the restriction phase and the occasional occurrence in other groups is also indicative of the fairly heavy physical activity.

Body Weights. The rate of body weight loss with calorie restriction is important because the more rapid the body weight loss, the more serious the degree of undernutrition. In this study, the body weight losses of the three calorie-restricted groups during the experimental periods were considerably less than we observed in previous studies (2, 4). These body weight losses averaged 256, 369 and 292 g/man/day for Groups I, II and III, respectively (Table 1B). In our previous studies, the mineral supplemented groups consuming 400 to 500 kcal/day, respectively, averaged losses of 410 g/day (2) and 518 g/day (4) during the 10 experimental days.

Brozek et al. (20) reported a loss of 600 g/man/day (or 7.7% of the total body weight in 12 days) with intakes of 580 kcal/day. It appeared that the greatest portion of the weight loss resulted from the large loss of body water at the beginning of the restriction period (20). Quinn et al. (21), studied men who consumed 900 kcal/day for 9 days, body weight losses averaged 465 to 611 g/man/day. However, during long-term calorie restriction up to 24 weeks, Keys et al. (22) reported body weight losses of 73 g/man/day in men who consumed approximately one-half of their daily dietary allowances.

It appears that the major portion of body weight losses in Groups I, II and III resulted from calorie deficit primarily. This deficit could account for 3.21, 2.82 and 2.37 kg of total body weight loss, if one assumes that only body fat was being utilized for energy. The inclusion of a factor combining the body fuels (protein, fat and glycogen) would result in a greater apparent calorie deficit and calculated body weight loss in these groups. The combined estimated body fat and water losses (2.07 kg from D_2O or 2.44 using estimated H_2O) can not readily account for the measured weight deficit in Group I (2.56 kg). However, if one calculates the body weight losses based solely on the calorie deficits, the losses for Groups II and III would be considerably less than the observed losses of body fat (-2.33, -2.34 kg) and body water (-0.05, -0.27 kg estimated, or -1.52, -1.82 kg - D_2O). This suggests an over-estimation of the changes in body fat and water compartments for Groups II and III.

Food and Nutrient Intakes. During the experimental period, the acceptability of the dry skim milk mix decreased drastically. To maintain the daily intakes at an acceptable level, chocolate syrup (15 g)

19. Department of the Army. Technical Bulletin (TB Med) No. 175, April 1969.
20. Brozek, J. et al. J Appl Physiol 10:412, 1957.
21. Quinn, M. et al. Metabolism 3:49, 1954.
22. Keys, A. et al. Human Starvation, Univ Minn Press, 1951.

was added to the diet. Although Group I ate essentially the whole daily issue, Groups II and III did not consume their complete ration, averaging 948 and 1362 kcal, respectively. The extremely low fat content may have contributed to the low acceptability of the diet mix. The fat content was intentionally kept low to increase the diet bulk for the lower intake groups, and to allow at least 100 g of carbohydrate and 40 g of protein.

Although the carbohydrate intakes averaged about 109 g/day in Group I, the subjects still showed consistent positive tests for ketone bodies in the urine. This suggests a combination of heavy physical activity, calorie restriction, and the utilization of body fat. There appeared to be an adaptive mechanism as Group I averaged only 5% incidence of ketone bodies, whereas the other groups had essentially none during the last 4 days of restriction.

The presence of ketone bodies in urine is not unusual during starvation since ketosis is closely associated with low carbohydrate intakes and starvation, and it has been attributed to a carbohydrate deficiency. Gamble (6) reported that 100 g of carbohydrate in the diet can reduce the incidence of ketosis. Ketosis reflects the incomplete metabolism of body fat to provide calories during periods of caloric deficits.

The thiamin and riboflavin/1000 kcal consumed were all above the NRC recommended daily allowances. However, the total daily calorie intakes were low in comparison to the NRC allowances (18). The niacin intakes were below the NRC daily allowances, whether reported in mg/1000 kcal or in mg/day. The magnesium intake for the restricted groups was considerably less than the NRC allowance.

Urine. The increased urine volumes in Groups I, II and III with concomitant decreases in specific gravity would indicate that these men were consuming sufficient fluids. In contrast, the reverse phenomenon in Group IV would suggest that some voluntary water restriction did occur under conditions of strenuous physical activity and high sweat rates. This again illustrates that thirst is not a measure of water requirements.

The daily urinary nitrogen excretions gradually and significantly decreased during the restriction period, which suggest some adaptation to the low daily intakes. These nitrogen excretions were considerably less than observed in the 500 kcal/day study where nitrogen excretion during the last 5 days of restriction averaged 10.6 g/day. Based on daily nitrogen intakes of 5.8 and 5.6 g/day, it appears that positive nitrogen balances could not be attained by Groups I and II, especially when the losses in sweat and feces have been considered.

Although Gamble (6) indicated that nitrogen losses could be reduced with 400 kcal of carbohydrate, Quinn et al. (21) have observed no improvements in negative nitrogen balances on intakes of 900 kcal/day.

However, Grande et al. (23) have suggested that protein catabolism could be reduced by increasing the carbohydrate intake from 580 to 1010 kcal/day. In our study, the additional 392 kcal from carbohydrate in Group II (over Group I) did not significantly reduce the nitrogen losses in comparison to Group I personnel who were consuming 436 kcal of carbohydrate. However, the additional calories, including more carbohydrate and protein for Group III, came close to obtaining a positive nitrogen balance. Group III had an averaged intake of 8.74 g of nitrogen and an urinary excretion that averaged 7.65 g/day during the last 6 days of restriction. Under conditions of our study, the increases in protein and carbohydrate intakes at the 1362 kcal/day level improved the nitrogen balance which was still negative. Had the sweat losses and fecal losses been included the degree of negative nitrogen balance would have been increased (Table 4).

The 10-day average urinary excretions of sodium and potassium, during restriction, exceeded the daily intakes for Groups I, II and III which indicate negative balances for these minerals. The average calcium and magnesium excretions in urine were considerably lower than the daily intakes and could suggest the possibility of positive balances. However the dermal or fecal losses of these minerals were not measured or included.

The major excretory route of calcium and magnesium is in the feces. The calcium intakes of more than 1 g/day are above the NRC daily allowances, and should be adequate in maintaining positive balances under these conditions (18). However, the average daily magnesium intakes are considerably below the NRC daily allowances and in this circumstance it appears that before balances can be estimated the fecal losses must be determined and included. In general, there appeared to be no adaptation to the various levels of magnesium intakes since the urinary excretions were approximately the same during the 10 days of restriction at the various levels of intake.

The negative potassium differences with daily intakes above 1.55 g/day are indicative of some body protein loss. Body potassium is closely associated with body protein and it has been calculated that a loss of 40 g of body protein is associated with a loss of 0.5 g of potassium.

Blood Values. Hematocrits and serum osmolalities were slightly decreased during the experimental period. The hematocrit values for Group I and III were not significantly different from either control or rehabilitation values. Significant decrease in serum osmolalities occurred across time. This is contrary to other restriction studies where decreases in hemoglobin and hematocrits were observed during the rehabilitation period, which suggested a dehydration effect during the experimental period. In the present study, body hypohydration was

23. Grande, F. et al. J Appl Physiol 12:202, 1958.

considerably less than reported in previous studies, and so the water retention effect during rehabilitation was expected to be minimal and as noted in Table 15 was minimal for all but Group II.

The decreases in plasma protein during restriction for Groups I, II and III are also contrary to data in previous studies of calorie restriction where increased serum protein levels were indicative of hemoconcentration. However, total body water losses were considerable in those studies (5, 24, 25). These data may be suggestive of the catabolism of body protein with resultant nitrogen losses, especially in Groups II and III.

<u>One-Hour Sweat and Urine Comparisons</u>. Sodium concentrations and excretions in sweat did not change appreciably during the 10 days of restriction, however, Groups I, II and III showed a rapid decrease in sodium urinary concentration and Groups I and II had falls in urine sodium excretion. While the men were consuming the normal diet with adequate sodium, the one-hour urinary excretions were about equal to the sweat excretions; but during restriction the sweat losses tended to be greater than the amounts lost in the urine. The data suggest that the urinary concentration of sodium is greatly dependent on the daily intake. The urinary potassium and magnesium concentrations increased throughout restriction for Groups I and II. Under these conditions, the quantity of potassium and magnesium were about the same in the sweat and urine, and it appears that the urinary and sweat concentrations of potassium and magnesium were not affected by the intake during this 10-day period.

The urinary and sweat concentrations of calcium are not affected by the daily dietary intake for 10 days. Although hourly urinary loss of calcium did not change, the calcium losses in the sweat were about 3 to 5 times as large as the amounts lost in the urine during the same period of time.

The significance of the sweat excretion of sodium, potassium and calcium in balance studies had been emphasized by Consolazio et al. (7). These data show the importance of the mineral losses in sweat that should be considered during balance studies (conducted in either a hot environment or during strenuous work) where the sweat rates may be abnormally high.

<u>Body Composition</u>. Fat showed the greatest body compartmental loss and was the primary energy source as the calorie deficit approximated the body weight loss, especially in Groups I, II and III.

The average body fat losses for Groups I, II and III during the experimental period were 1.64, 2.33 and 2.34 kg respectively and for the entire study 2.40, 2.60 and 1.66 kg. The greatest loss of body fat in the experimental period in Group III was unexpected, especially since

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24. Krzywicki, H.J. et al. Am J Clin Nutr 25:67, 1972.
25. Krzywicki, H.J. et al. Am J Clin Nutr 21:87, 1968.

the calorie deficit can account for a maximum of only 2.2 kg if one considers body fat being utilized as energy. This group also lost the most total body water. Although Group IV subjects did lose 1.47 kg of fat during the experimental period and 1.63 over the entire period, this could suggest some redistribution of the body compartments as indicated by the slight increases in blood and plasma volume, total body water, and body proteins.

Brozek et al. (20), in a study of men consuming 580 kcal/day, reported that the body fat loss constituted 40% of the total body weight loss (or 190 g/day), whereas in our 420 kcal/day study the subjects lost 98 g of fat per day. In the 500 kcal/day study (5), the mineral-supplemented group lost an average of 276 g/man/day. This suggests that with the addition of protein in the diet, the body fat stores were mobilized and utilized to a greater extent. The body fat losses in this study closely resembled the data observed during starvation (25). Allen and Musgrave (26) have suggested that the two compartment systems were inadequate for defining compartments with any accuracy in other than obese individuals on 400 kcal/day regimens. The data suggest that body fat losses represented 64.1, 63.1, and 80.1% of the body weight losses in Groups I, II and III during restriction. The continued loss of body fat in Groups I, II and IV during rehabilitation was unexpected.

The other major body compartment losses during restriction were observed in the water phases. The maximal decreases in blood volume occurred during Day 4 of restriction for Groups I, II and III. The plasma volume data suggested the same trends for the same groups, with a lesser loss of plasma volumes during the last day of restriction for Groups I and II (7.6 and 9.9%). The values for Groups I and III were less than 13.7% decrease in blood volume (Group II, 15.3 % decrease on day 4 of the experimental period) and less than 11.4% decrease in plasma volume (Group II, 12.9% decrease on day 4 of the experimental period) reported in the 420 kcal/day study (24).

Total body water by deuterium dilution indicated losses of 0.43, 1.52, and 1.82 kg for Groups I, II and III, respectively but these losses were not significant. These values are in the same approximate range of total body water losses of 1.32 kg for the mineral-supplemented men in the 500 kcal/day study (5).

The total body water losses estimated from deuterium dilution exceeded the values derived from densitometry by at least 1 kg in subjects in Groups II and III and in the past two laboratory studies (24). For Group I the loss by D_2O was about one half of that by densitometry. The reduction in blood and plasma volumes on the fourth day of restriction would suggest that the deuterium procedure would be more comparable and applicable under these conditions, and would indicate a loss of total

26. Allen, T.H. and P.W. Musgrave. Am J Clin Nutr 24:14, 1971.

body water. These data serve to emphasize the fact that negative water balances do occur with calorie restriction. These losses were also verified by the water balance data reported earlier by Johnson et al. (5) where negative water balances were observed during caloric restriction. Lastly, although minerals appeared to conserve water, only a minor difference in the per cent total body water as body weight was observed.

Had the sodium and potassium intakes been adequate, one would not expect to see any great changes in the extracellular and intracellular water. The means for all groups were significantly increased by the second measurement during the experimental period (ANOVA).

Body water losses or negative water balances are closely related to the daily sodium intakes. While it must again be emphasized that the three restricted groups were permitted salt and water ad libitum it should again be noted that all three groups were in a negative sodium balance. This may be another reason for the reduced body weights in comparison to other studies. Although some body water was lost by the restricted groups, these losses could have been greater if the salt intake had been purposely restricted. This has been indicated by Rogers et al. (27) and Taylor et al. (28), who suggested that sodium salt would reduce ketonuria and hypoglycemia in the presence of restricted intakes and minimize body water losses. However, our data suggest that although body water losses were low, the ketonuria was still present in the group consuming the lowest calories.

Our 500 kcal/day study (5) and data by Brozek et al. (20) indicate that 8.4 and 9.0% of the body weight loss was due to body protein loss. Since the protein estimate is calculated as only 20.2% of the fat free mass, small changes could be masked in the densitometric technique. However, in the two laboratory studies (24, 25) the body protein losses for the mineral-supplemented group were fairly large, averaging 0.64 and 0.39 kg, respectively. This was considerably more than the protein losses in Groups I, and III, and not in line with the increase noted for Groups II and IV. This was unexpected since the lower intake groups would probably utilize more protein for energy under conditions of calorie restriction.

Skin folds and Circumferences. Skin fold thickness measurements suggested no significant differences between the control and experimental periods. This was unusual and did not agree with data in previous studies where the skin fold thickness measurements were greatly reduced (25). During 10 days of complete starvation (25), the scapula and tricep skin folds were reduced by 24.1 and 21.6%, and by 7.8 and 15.0%, respectively during the 420 kcal/day study (24), and by 14.7 and 22.4%

27. Rogers, T.A. et al. J Appl Physiol 19:1, 1964.
28. Taylor, H.L. et al. J Appl Physiol 10:421, 1957.

during the 500 kcal/day study (25). The data from the latter two studies are on mineral-supplemented groups that lost less body weight. Although many studies have demonstrated that skin fold thickness measurements may be an excellent index of the state of obesity or fatness of an individual, this study suggests that this may not apply under some conditions.

The small changes in biceps circumferences, as observed in this study, are in agreement with the data from the 420 and 500 kcal/day studies (24, 25) where the decrease averaged 0.6 and 3.7%, respectively, when minerals were available. However, in the complete 10-day starvation study (25), the bicep circumference decreases averaged 9.8%, which were considerably lower than the 18.4% decrease observed by Keys et al. (22) in their long-term semi-starvation study.

The fairly small decreases in the calf circumference of 0 - 3.4% in the three restricted groups are in the same approximate range of losses in past studies where a decrease of 3.2%, 3.4% and 3.0% was observed in the starvation, 420 kcal and 500 kcal/day studies, respectively (24, 25). These data indicate that the calf circumferences are not one of the better measurements of fatness-leanness in humans.

As in past studies by our laboratory (24, 25), the forearm circumferences showed no significant changes during the restriction period. A decrease of only 3.4% was observed in the 10 days of starvation (25). It appears that the forearm may be a poor indicator of body fat loss especially in physically active and conditioned men.

The decrease in buttocks circumferences was also small, ranging from 1.1 to 1.8% in the three restricted groups. In the long-term study by Keys et al. (22), the decrease averaged 8.8%, whereas in our three laboratory studies the average decreases in buttock circumferences were 5.8, 2.7 and 3.0%, respectively (24, 25). The waist circumferences showed the largest decreases (-1.9 to -3.7%) of any of the circumference measurements, but these were still less than the decreases observed in past studies (5.1 to 6.0%) and considerably lower than the value observed in the long-term study by Keys et al. (22).

Pulmonary Function. The pulmonary function data show some small, inconsistent, non-significant changes during the restriction periods. The exception is the MBC frequency (R/min) for Group III.

The increases in MBC for Groups I and III resulted in a 6.1 and 13.4% increase in the MBC frequency for the same groups. The three restricted groups showed an increase in ERV (ANOVA) with Group II and III values increased by 12.9 and 13.1% during restriction.

The data indicate that under conditions of this study, the pulmonary measurement showed only minor variability during the experimental

period. Although the ERV data demonstrated a consistent increase -- and the IC data showed a biologically insignificant decrease, it appears that the stress of calorie restriction and heavy physical activity with the resultant weight loss did not improve pulmonary function. This, of course, may have been due to the fact that the men were in good physical condition and acclimated to the heat and activity prior to the beginning of the study.

Performance. The daily energy expenditure of the subjects would appear to have been relatively high throughout the entire study. This assumption is based upon negligible weight changes (Table 1B) of the control Group IV during the 10-day experimental period while their caloric intakes averaged 3301 kcal/day. The oxygen consumption during maximal work (Table 25) indicated that these subjects were physically fit. The major portion of the reduction in oxygen consumption during caloric restriction could be attributed to the reduced body weights since these differences were significant for values expressed on the basis of body weights.

Henschel et al. (29), in their 5-day starvation study, observed a 45% decrement in performance using the Harvard Fitness Test, and 7.7% decrease in maximal $\dot{V}_{O_2}$ l/min. When calculated in $\dot{V}_{O_2}$ ml/kg/min, there were no significant differences observed in the present study.

The study of Taylor et al. (28) of men who consumed 580 kcal/day of carbohydrate for 12 days was more comparable to our present caloric restriction study. These investigators reported small changes in maximal $\dot{V}_{O_2}$ in liters/min during caloric restriction, and as in our study when converted to $\dot{V}_{O_2}$ ml/kg/min, they also observed essentially no changes from control values: in essence, the maximal $\dot{V}_{O_2}$ decreases in proportion to the body weight loss may reflect a decrease in muscle mass. The 24-week study by Keys et al. (22) demonstrated that prolonged semi-starvation resulted in a 40% decrease in maximal $\dot{V}_{O_2}$ in ml/kg/min, and a 70% decrement in maximal performance on the Harvard Fitness Test, but these men lost 24% of their initial body weight including 430 g of nitrogen. It appears that a loss of 40 to 50 g of nitrogen during short-term caloric restriction does not require a long rehabilitation period. Rehabilitation in this study was rapid. In the long-term study by Keys et al. (22), rehabilitation was slow (20 weeks). Although the maximal work times on the treadmill and the maximal heart rates were not significantly different between groups or between control and restriction periods, the sum of recovery heart rates were reduced in all groups during the experimental phase. This resulted in an increase in physical fitness scores by the end of the study which suggests a greater physical efficiency and physical conditioning. Both physical conditioning and heat acclimatization appear to be associated with improvements of cardiovascular function during heavy work, expecially in a hot environment. This includes a lower heart rate with better recuperative powers after exhausting exercise (30). Motivation plays an

29. Henschel, A. et al. J Appl Physiol 6:624, 1954.
30. Buskirk, E.R. et al. J Appl Physiol 12:189, 1958.

important role in physical performance. An individual with poor morale and low motivation will not perform adequately.

The data on work performance suggest that the concept of body weight loss with hypohydration in excess of 10% resulting in rapid deterioration of maximal $\dot{V}_{O_2}$ may be valid (22). In the present and previous studies, where the body weight loss was below 10%, the subjects were able to maintain the capacity to perform both aerobic and anaerobic work adequately. In part, this could be attributed to the effects of the carbohydrate and mineral-supplemented diets in reducing the body weight and body water losses, and thereby acting as a protective mechanism in maintaining maximal efficiency. The results of this study indicate, as the other studies suggested, that normal men can perform physical work adequately during short-term caloric restriction. It is unfortunate that tests were not performed to evaluate the impact of diet upon other forms of performance, eg - mental acuity, cognition, etc.

CONCLUSIONS AND RECOMMENDATIONS

Four groups of physically conditioned, heat-acclimated men consumed 585, 948, 1362 and 3301 kcal/day for a 10-day period during maneuvers in a jungle environment. In the three calorie-restricted groups, the body weight losses were minimal in comparison to previous laboratory studies. The loss in body weight was calculated to be primarily body fat that approximated 2.3 to 3.2% of the initial body weight and total body waters that approxmated 0.6 to 2.2% of the initial body weights.

The data demonstrated that nitrogen balances could not be attained on 1362 kcal/day under the conditions of this study. No significant differences were observed in the results of physiological work capability in the experimental period when comparing them to the control values.

Under the conditions of this study, it is suggested that with fairly heavy physical activity, an intake of greater than 1360 kcal/day, containing an adequate intake of minerals and water, is necessary to prevent a negative nitrogen balance but an intake of 1360 kcal/day will prevent loss of physiological work performance in men for short periods of time of up to 10 days.

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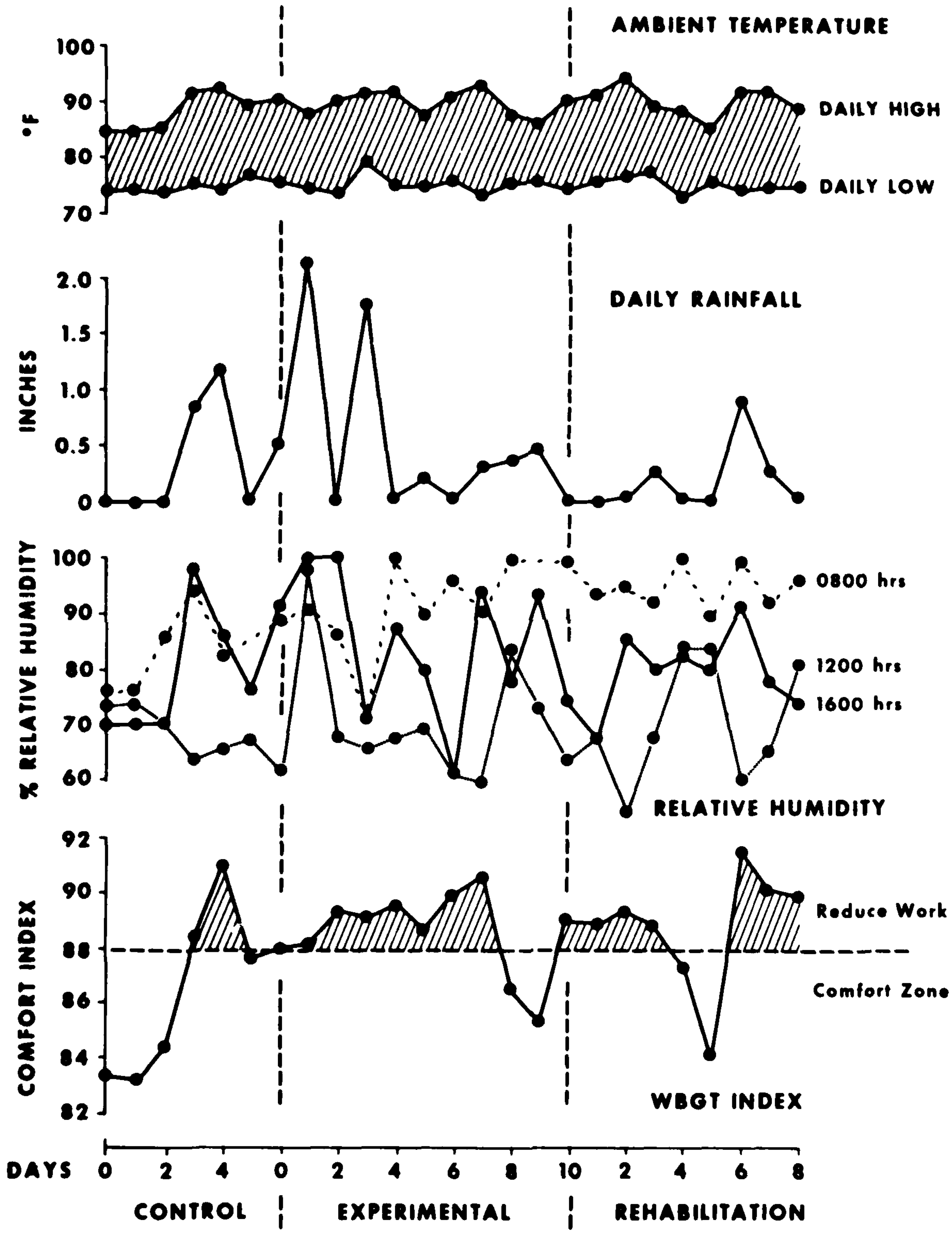
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°F
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DAILY LOW
DAILY RAINFALL
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0
INCHES
% RELATIVE HUMIDITY
100
90
80
70
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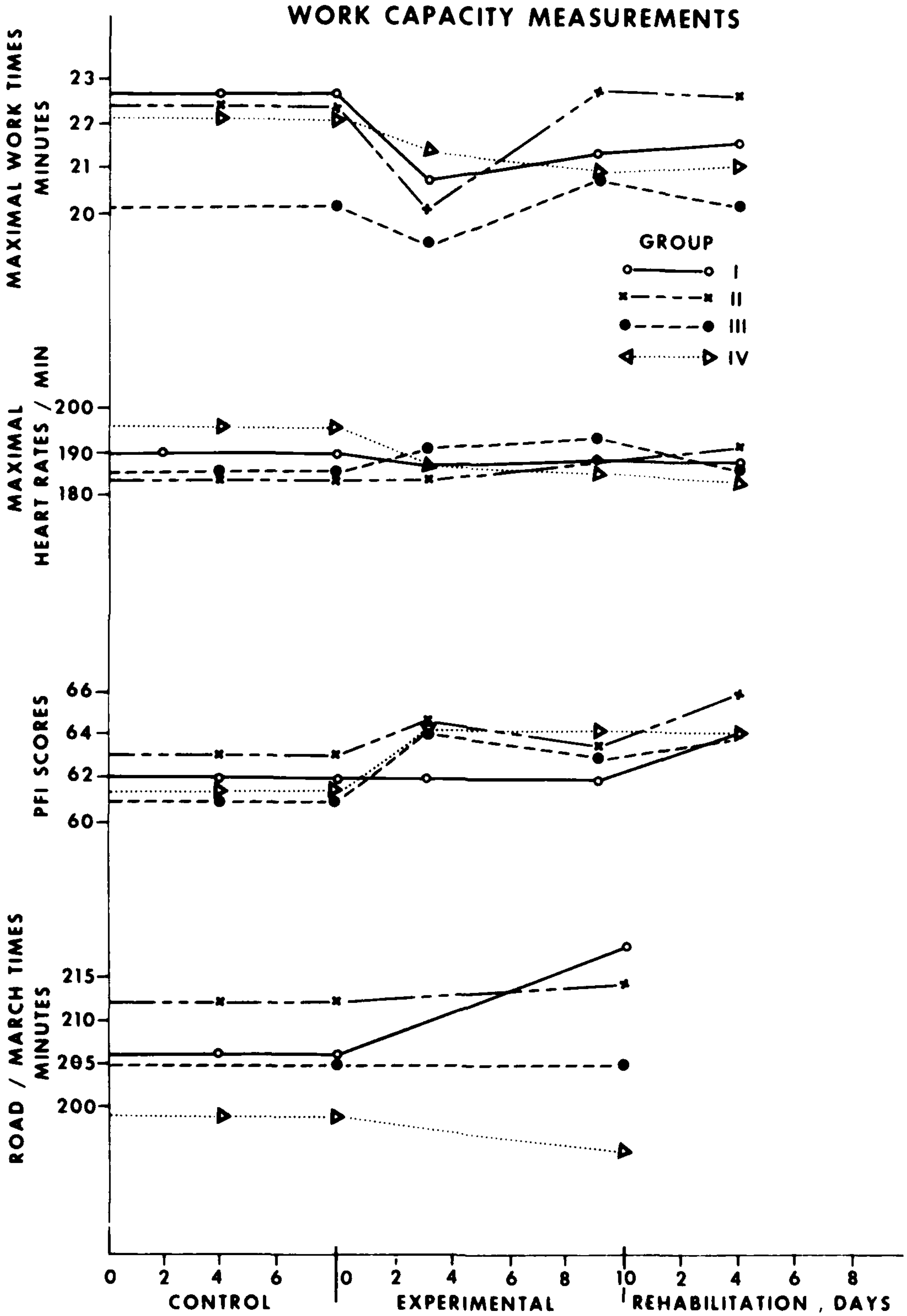
0800 hrs
1200 hrs
1600 hrs
RELATIVE HUMIDITY
COMFORT INDEX
92
90
88
86
84
82
Reduce Work
Comfort Zone
WBGT INDEX
DAYS 0 2 4 0 2 4 6 8 10 2 4 6 8
CONTROL
EXPERIMENTAL
REHABILITATION

FIGURE 1



WORK CAPACITY MEASUREMENTS
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III
IV
MAXIMAL
HEART RATES / MIN
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190
180
PFI SCORES
66
64
62
60
ROAD / MARCH TIMES
MINUTES
215
210
205
200
0
2
4
6
0
2
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6
8
10
2
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CONTROL
EXPERIMENTAL
REHABILITATION , DAYS

FIGURE 2

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Table 1-A. Mean body weight changes (kg) during the different periods.

Group	No./Group	Control Weight[1] (kg)	Difference from Control Weight			
			Experimental		Rehabilitation	
			Day 10	Day 26	Day 2	Day 8
I	18	72.3 ± 17.8	-2.95		-1.11	-0.96
II	18	73.8 ± 7.3	-3.47		-1.75	-1.53
III	16	73.5 ± 7.2	-3.09		-1.15	-1.64
IV	19	69.6 ± 9.5	+0.24		+0.59	+0.08
V	18	72.0 ± 9.5		-1.40	-	-
VI	18	70.9 ± 9.8		-0.98	-	-

1- Mean ± Standard Deviation.

Within Groups I, II, and III all weights obtained on the days indicated for the experimental and rehabilitation periods were significantly different (P<0.05) from the control weights. Final experimental period weights for Groups V and VI were significantly different than control weights.

Table 1-B. Mean body weight changes (kg) during the different periods for intensively studied personnel.

Group	No./Group	Control Weight[1] (kg)	Difference from Control Weight			
			Experimental		Rehabilitation	
			Day 10	Day 26	Day 2	Day 8
I	10	71.1 ± 18.5	-2.56*		-0.93*	-0.98
II	11	73.8 ± 8.3	-3.69*		-1.69*	-1.35*
III	7	79.4 ± 4.0	-2.92*		-3.27*	-1.66*
IV	10	71.2 ± 8.8	-0.04		+0.33	+0.05
V	10	69.2 ± 9.5		-1.37*	-	-
VI	8	66.8 ± 10.2		-0.88	-	-

1- Mean ± Standard Deviation

*Weight was significantly different ($P<0.05$) from control. Control weights of personnel from Group III who were intensively studied were significantly different ($P<0.01$) from the other personnel of that Group. Control weights of personnel intensively studied in the other groups were representative of their groups.

Table 2. Mean daily nutrient intakes[1] during 10 day experimental period.

Nutrient	Group I	Group II	Group III	Group IV
Calories, kcal	585 ± 46	948 ± 76	1362 ± 38	3301 ± 380
Carbohydrate, g	109 ± 8	207 ± 11	292 ± 10	441 ± 15
Fat, g	1.03 ± 0.21	1.64 ± 0.38	2.70 ± 0.14	105 ± 10.2
Protein, g	36.2 ± 3.8	34.7 ± 7.2	54.4 ± 2.7	142 ± 8.5
Thiamin, mg	0.52 ± 0.06	0.57 ± 0.07	0.86 ± 0.06	2.05 ± 0.18
Riboflavin, mg	1.82 ± 0.19	1.70 ± 0.36	2.66 ± 0.12	3.27 ± 0.27
Niacin, mg	1.35 ± 0.30	2.20 ± 0.16	2.73 ± 0.12	32.9 ± 1.62
Sodium, mg	552 ± 57	774 ± 157	1324 ± 178	3796 ± 540
Potassium, mg	1894 ± 174	1900 ± 348	2929 ± 149	2674 ± 200
Calcium, mg	1306 ± 132	1318 ± 263	2091 ± 95	1199 ± 100
Magnesium, mg	112 ± 11	115 ± 23	188 ± 8	476 ± 15

1-Mean ± Standard Deviation

Table 3. Mean daily urine volumes, specific gravity, pH and total solids.

	Periods		
Group	Control	Experimental	Rehabilitation
		Volume, g/day	
1	938 ± 140[1]	980 ± 255	1039 ± 185
II	1027 ± 135	1032 ± 158	1313 ± 207
III	1234 ± 176	852 ± 289*	1154 ± 299
IV	1061 ± 146	1117 ± 261	1103 ± 261
		Specific Gravity	
I	1.019 ± .001	1.017 ± .003	1.018 ± .002
II	1.019 ± .001	1.015 ± .001*	1.017 ± .002
III	1.019 ± .002	1.021 ± .003	1.020 ± .003
IV	1.019 ± .001	1.019 ± .002	1.019 ± .002
		pH	
I	6.0 ± 0.1	5.9 ± 0.2	6.0 ± 0.2
II	6.0 ± 0.2	6.2 ± 0.2	6.2 ± 0.2
III	6.1 ± 0.2	6.2 ± 0.3	6.1 ± 0.2
IV	5.9 ± 0.2	6.0 ± 0.3	5.9 ± 0.2
		Total Solids, %	
I	4.2 ± 0.4	3.8 ± 0.5	4.0 ± 0.4
II	4.0 ± 0.3	3.2 ± 0.2	3.7 ± 0.5
III	4.1 ± 0.4	4.4 ± 0.5	4.4 ± 0.6
IV	4.0 ± 0.3	4.1 ± 0.3	4.0 ± 0.4

*Significantly different from control values at $P<0.05$.

1-Mean ± Standard Deviation

Table 4. Daily intake and urinary excretion of nitrogen, sodium, potassium, calcium and magnesium during the experimental period[1,2].

Group	Dietary Intake	Urinary Excretion	Difference
		Nitrogen, g	
I	5.79 ± 0.61	8.55 ± 2.20	-2.76
II	5.55 ± 1.15	7.97 ± 1.36	-2.42
III	8.70 ± 0.43	9.07 ± 1.38	-0.37
IV	22.70 ± 1.36	14.18 ± 1.9[illegible]	+8.52
		Sodium, mg	
I	552 ± 57	1397 ± 1101	-845
II	774 ± 157	1251 ± 906	-477
III	1324 ± 179	1625 ± 1220	-301
IV	3796 ± 540	3797 ± 1636	- 1
		Potassium, mg	
I	1894 ± 174	1993 ± 960	- 99
II	1900 ± 348	2266 ± 837	-366
III	2929 ± 149	3030 ± 968	-101
IV	2674 ± 200	2783 ± 1052	-109
		Calcium, mg	
I	1306 ± 132	114 ± 57	+1192
II	1318 ± 263	116 ± 76	+1202
III	2091 ± 95	96 ± 57	+1995
IV	1199 ± 100	154 ± 76	+1045
		Magnesium, mg	
I	112 ± 11	81 ± 31	+ 31
II	115 ± 23	79 ± 26	+ 36
III	188 ± 8	87 ± 32	+101
IV	476 ± 15	96 ± 34	+380

1-Mean ± Standard Deviation

2-Absence of fecal and sweat loss data precludes calculation of nutrient balance.

Table 5. Fasting blood values for: hemoglobin, hematocrit, glucose, urea nitrogen.[1]

	Period			
	Control	Experimental		Rehabilitation
Group	Day 6	Day 4	Day 10	Day 7
		Hemoglobin, g/dl		
I	14.6 ± 0.5^{2}	14.8 ± 0.6^{2}	14.8 ± 0.6	14.8 ± 0.7
II	$15.2 \pm 0.7^{1,4}$	$15.6 \pm 0.7^{1,4}$	15.3 ± 0.7^{4}	15.3 ± 0.5^{4}
III	14.0 ± 0.9	15.2 ± 0.9	14.8 ± 1.0	14.9 ± 0.7
IV	14.3 ± 0.4^{2}	$14.8 \pm 0.4^{2,a}$	14.5 ± 7.0^{2}	14.6 ± 0.6^{2}
		Hematocrit, %		
I	48 ± 3	$48 \pm 2^{3,4}$	46 ± 3	46 ± 3^{4}
II	$50 \pm 2^{4,b}$	$48 \pm 2^{3,4,a}$	$48 \pm 2^{3,a}$	$47 \pm 2^{4,a}$
III	48 ± 3	$46 \pm 2^{1,2}$	45 ± 4^{2}	45 ± 3
IV	$46 \pm 1^{2,b}$	$44 \pm 2^{1,2,a}$	46 ± 3^{b}	$43 \pm 2^{1,2,a}$
		Glucose, mg/dl		
I	90 ± 4	88 ± 7	89 ± 8	88 ± 6^{2}
II	93 ± 8	90 ± 8	91 ± 7	94 ± 6^{1}
III	92 ± 10	92 ± 7	90 ± 7	92 ± 6
IV	89 ± 3	91 ± 4	94 ± 4^{a}	93 ± 7
		Urea Nitrogen, mg/dl		
I	$13.3 \pm 1.2^{2,3,4}$	$14.6 \pm 1.7^{b,c}$	$12.2 \pm 1.1^{4,a,c}$	$12.7 \pm 0.9^{2,3,4}$
II	15.2 ± 1.6^{1}	13.8 ± 2.6^{b}	$12.8 \pm 3.4^{4,b}$	17.0 ± 2.9^{1}
III	15.2 ± 2.5^{1}	14.1 ± 1.8	13.4 ± 2.1^{4}	15.6 ± 3.0^{1}
IV	16.6 ± 2.0^{1}	16.0 ± 2.6	$16.5 \pm 2.2^{1,2,3}$	15.4 ± 2.4^{1}

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c= difference between days of experimental period.

Table 6. Fasting plasma and serum values for: total proteins; osmolality; and free fatty acids.[1]

Group	Control Day 6	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
Plasma Total Proteins, g/dl				
I	7.8 ± 0.6^{2}	8.0 ± $0.4^{3,4}$	7.6 ± 0.6	7.6 ± 0.5
II	8.4 ± $0.3^{1,3,4,b}$	8.1 ± $0.3^{3,4}$	7.8 ± $0.4^{3,a}$	8.0 ± $0.5^{3,a}$
III	7.6 ± 0.3^{2}	7.3 ± $0.3^{1,2}$	7.2 ± $0.4^{2,4,a}$	7.4 ± 0.4^{2}
IV	7.8 ± 0.5^{2}	7.6 ± $0.3^{1,2}$	7.9 ± 0.5^{3}	7.6 ± 0.3
Serum Osmolality, mOsm/l				
I	301 ± $3^{2,3,4,b}$	296 ± $4^{2,4,a}$	293 ± $4^{3,a}$	292 ± $9^{3,a}$
II	305 ± $5^{1,b}$	301 ± $4^{1,c}$	290 ± $5^{3,4,a,b,c}$	298 ± 9^{a}
III	305 ± $3^{1,b}$	299 ± $2^{4,a}$	300 ± $4^{1,2,a}$	299 ± $5^{1,a}$
IV	305 ± $5^{1,b}$	304 ± $4^{1,3,b}$	301 ± 12^{2}	296 ± 8^{a}
Serum Free Fatty Acids, mEq/l				
I	730 ± 182	770 ± 222	742 ± 185	608 ± 131
II	695 ± 254	770 ± 317	615 ± 174	648 ± 178
III	665 ± 152	871 ± 474	620 ± 164	660 ± 253
IV	653 ± 217	1175 ± $613^{a,b}$	765 ± 269	684 ± 217

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c= difference between days of experimental period.

Table 7. Fasting serum values for: sodium, potassium, calcium and magnesium.[1]

Group	Periods			
	Control	Experimental		Rehabilitation
		Day 4	Day 10	Day 7
		Sodium, mEq/L		
I	141.0 ± 4.6	145.0 ± 4.6[b]	141.6 ± 3.8	140.3 ± 2.8[4]
II	141.4 ± 4.4	143.4 ± 5.0	144.5 ± 4.6[3]	140.9 ± 3.8
III	139.8 ± 4.0	141.2 ± 5.7	138.2 ± 3.6[2]	140.1 ± 5.1
IV	141.9 ± 5.5	145.1 ± 4.7	142.1 ± 6.1	143.8 ± 3.9[1]
		Potassium, mEq/L		
I	5.2 ± 0.4	5.3 ± 0.3	5.3 ± 0.3	5.4 ± 0.3
II	5.2 ± 0.4	5.2 ± 0.2	5.2 ± 0.3	5.2 ± 0.2
III	5.1 ± 0.2	5.1 ± 0.3	5.2 ± 0.3	5.2 ± 0.2
IV	5.1 ± 0.3	5.1 ± 0.2	5.1 ± 0.2	5.2 ± 0.2
		Calcium, mg/dl		
I	9.8 ± 0.3[2,b]	10.2 ± 0.5	9.9 ± 0.3[2,4,b]	10.2 ± 0.2[a]
II	10.6 ± 0.3[1,3,4]	10.5 ± 0.6[4]	10.3 ± 0.4[1]	10.4 ± 0.3
III	9.9 ± 0.5[2]	9.9 ± 0.6	9.8 ± 0.7	10.0 ± 0.5
IV	10.0 ± 0.3[2]	10.0 ± 0.4[2]	10.2 ± 0.2[1]	10.2 ± 0.2
		Magnesium, mEq/L		
I	1.92 ± 0.09[2,3]	1.90 ± 0.09	1.94 ± 0.10	1.87 ± 0.11[2,3,4]
II	2.02 ± 0.08[1,4]	1.97 ± 0.14	1.98 ± 0.09	1.97 ± 0.10[1]
III	1.98 ± 0.11[1]	1.95 ± 0.10	1.94 ± 0.12	1.99 ± 0.09[1]
IV	1.92 ± 0.14[2]	1.95 ± 0.13	1.93 ± 0.11	2.02 ± 0.13[1]

1-Mean ± Standard Deviation

Between groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 8. One hour sweat and urine output.[1]

Group	Control: Day 6	Experimental: Day 4	Experimental: Day 10	Rehabilitation: Day 7
	Sweat Collection, g/1 hr			
I	300 ± 262^{3,4}	562 ± 193^{a}	520 ± 281	514 ± 192^{2,3,4}
II	450 ± 229^{3,4,b}	491 ± 252^{c}	945 ± 361^{a,c}	694 ± 146^{1,3,a}
III	801 ± 86^{1,2}	729 ± 178	839 ± 217	888 ± 94^{1,2}
IV	702 ± 315^{1,2}	631 ± 276	579 ± 366	810 ± 241^{1}
	Urine Collection g/1 hr			
I	96 ± 30	76 ± 24	64 ± 29^{4,a}	72 ± 42
II	98 ± 32	100 ± 25^{c}	64 ± 21^{4,a,b,c}	101 ± 23^{3}
III	82 ± 43	82 ± 33	71 ± 30^{4}	74 ± 21^{2,4}
IV	94 ± 34	92 ± 31	104 ± 17^{1,2,3}	103 ± 23^{3}

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III: and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control: b=different from rehabilitation period: and c=difference between days of experimental period.

Table 9. Sodium levels in one hour sweat and urine collection.[1]

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
		Sweat Concentration, mg/kg		
I	379 ± 178[3]	595 ± 354[3]	657 ± 309	592 ± 357
II	610 ± 273	591 ± 377	830 ± 403[b]	463 ± 107[3]
III	774 ± 243[1]	286 ± 137[1,a,b,c]	568 ± 189[c]	665 ± 208[2]
IV	603 ± 350	441 ± 280	887 ± 492	560 ± 194
		Sweat Excretion, mg/hour		
I	153 ± 214[3]	346 ± 258	383 ± 319	332 ± 296
II	276 ± 178[3]	274 ± 260[c]	725 ± 260[3,a,b,c]	328 ± 138[3]
III	631 ± 225[1,2]	217 ± 102[a,b,c]	478 ± 194[2,c]	581 ± 163[2]
IV	452 ± 363	262 ± 188	565 ± 530	480 ± 288
		Urine Concentration, mg/kg		
I	6367 ± 2405[b]	1908 ± 983[4,a,b]	2806 ± 1920[4,a]	4805 ± 2726[2,a]
II	5265 ± 2004	2444 ± 2208[a]	3283 ± 1250[4,a]	2663 ± 1203[1]
III	5576 ± 1501[b]	3013 ± 1590[a]	4275 ± 1634	3602 ± 1092[a]
IV	4524 ± 1958	4350 ± 2525[1]	5438 ± 2115[1,2]	3510 ± 2132
		Urine Excretion, mg/hour		
I	583 ± 262[b]	271 ± 367	200 ± 198[4,a]	353 ± 340[a]
II	518 ± 252	236 ± 217[a]	205 ± 110[4,a]	247 ± 73
III	491 ± 327	233 ± 156	316 ± 171	592 ± 865
IV	386 ± 178	385 ± 208	592 ± 306[1,2]	371 ± 265

1-Mean ± Standard Deviation

Between Groups: Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are indicated by superscript: a=different from control: b=different from rehabilitation period; and c=difference between days of experimental period.

Table 10. Potassium levels in one hour sweat and urine collections.[1]

Group	Periods: Control	Experimental: Day 4	Experimental: Day 10	Rehabilitation
	Sweat Concentration, mg/kg			
I	320 ± 179	391 ± 165[3]	686 ± 282[3,a,c]	468 ± 296
II	452 ± 189[3,4]	563 ± 247[3]	444 ± 230[3]	447 ± 57[3]
III	247 ± 53[2,b]	188 ± 58[1,2,b]	219 ± 72[1,2,4,b]	383 ± 31[2,a]
IV	304 ± 104[2,b]	336 ± 265	731 ± 399[3,a,b]	439 ± 55[a]
	Sweat Excretion, mg/hour			
I	117 ± 128	280 ± 143	404 ± 300	240 ± 158
II	199 ± 133[b]	243 ± 124	404 ± 222[3,a]	310 ± 67[a]
III	204 ± 29[b]	169 ± 86[b]	185 ± 75[2,4,b]	312 ± 51[a]
IV	210 ± 106[b]	166 ± 98[b,c]	240 ± 150[c]	356 ± 116[a]
	Urine Concentration, mg/kg			
I	2428 ± 891[2]	3263 ± 2085[4]	4225 ± 2243[a,b]	2098 ± 962
II	3621 ± 977[1,4,b]	2957 ± 1800[c]	4563 ± 1270[b,c]	2070 ± 476[4,a]
III	2819 ± 653	3600 ± 1262[b]	4898 ± 777[a,b]	2304 ± 602
IV	2466 ± 814[2]	3647 ± 1685[1]	3888 ± 1364[a]	2871 ± 1061[2]
	Urine Excretion, mg/hour			
I	220 ± 78[2]	208 ± 125	262 ± 190	152 ± 132[4]
II	361 ± 173[1,b]	283 ± 181	292 ± 133	202 ± 47[4,a]
III	241 ± 160	310 ± 202	348 ± 138[a,b]	170 ± 63[4]
IV	246 ± 127	339 ± 228	388 ± 91[a]	289 ± 114[1,2,3]

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 11. Calcium levels in one hour sweat and urine collections.[1]

Group	Control (Periods)	Experimental: Day 4	Experimental: Day 10	Rehabilitation
	Sweat Concentration, mg/kg			
I	138 ± $28^{3,4,b}$	50 ± $21^{2,a,c,}$	100 ± $9^{3,a,c}$	80 ± 41^{a}
II	108 ± $48^{3,4}$	77 ± $28^{1,3}$	61 ± 39^{a}	82 ± 41
III	56 ± $29^{1,2}$	42 ± 22^{2}	52 ± 22^{1}	57 ± 19
IV	69 ± $22^{1,2}$	68 ± 44	73 ± 56	64 ± 20
	Sweat Excretion, mg/hour			
I	36 ± 22	29 ± 17	52 ± 29	40 ± 25
II	45 ± 18	34 ± 22	55 ± 41	54 ± 21
III	43 ± 17	31 ± 14^{b}	46 ± 13	50 ± 13
IV	48 ± 21	34 ± 13^{b}	34 ± 27	57 ± 25
	Urine Concentration, mg/kg			
I	80 ± 38^{3}	70 ± 53	145 ± 96^{a}	147 ± 89
II	121 ± 55	127 ± 82	158 ± 36	139 ± 67
III	145 ± 66^{1}	98 ± 55	133 ± 78	120 ± 56
IV	140 ± 76	99 ± 68	144 ± 68	165 ± 10^{2}
	Urine Excretion, mg/hour			
I	8 ± 4	5 ± 4^{2}	9 ± 6	8 ± 4^{4}
II	12 ± 8	12 ± 7^{1}	10 ± 4	13 ± 6
III	10 ± 5	7 ± 4	9 ± 3	9 ± 6
IV	12 ± 8	9 ± 8	15 ± 7	18 ± 12^{1}

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period: and c=difference between days of experimental period.

Table 12. Magnesium levels in one hour sweat and urine collections.[1]

Group	Control	Experimental: Day 4	Experimental: Day 10	Rehabilitation
		Sweat Concentration, mg/kg		
I	10 ± 6	8 ± 6^{b}	13 ± 2^{3}	25 ± 22^{4}
II	9 ± 7	10 ± 3^{3}	7 ± 5	13 ± 12
III	6 ± 2	5 ± 2^{2}	4 ± $1^{1,a,b}$	6 ± 2
IV	7 ± 3	8 ± 6	8 ± 7	7 ± 2^{1}
		Sweat Excretion, mg/hour		
I	3 ± 3	5 ± 5	6 ± 3^{3}	14 ± 16
II	4 ± 3	5 ± 3	6 ± 4	8 ± 6
III	5 ± 1	4 ± 2	4 ± $0.5^{1,b}$	6 ± 1
IV	5 ± 2	4 ± 2	5 ± 3	6 ± 2
		Urine Concentration, mg/kg		
I	50 ± $54^{3,4}$	81 ± 34	115 ± 52^{a}	84 ± 38
II	70 ± $39^{3,4}$	88 ± 57	135 ± $65^{a,b}$	71 ± 36^{4}
III	123 ± $48^{1,2}$	74 ± 39	130 ± 54	87 ± 30
IV	105 ± $27^{1,2}$	102 ± 45	110 ± 33	109 ± 28^{2}
		Urine Excretion, mg/hour		
I	4 ± 6^{4}	6 ± 3	7 ± 4^{4}	5 ± 3^{4}
II	7 ± 5	8 ± 5	9 ± 6	7 ± 4^{4}
III	8 ± 4	7 ± 5	10 ± 3	7 ± 4^{4}
IV	10 ± 3^{1}	10 ± 6	11 ± 3^{1}	11 ± $3^{1,2,3}$

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 13. Plasma and blood volume (ml) during the different periods.

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation
		Plasma Volume, ml		
I	2990 ± 268^{3,4}	2672 ± 330^{3,4,a}	2764 ± 449^{3,4}	2799 ± 371^{3,4}
II	3399 ± 1009^{1}	2959 ± 486^{4}	3061 ± 560^{1}	3375 ± 891^{1}
III	3404 ± 291^{1}	3199 ± 256^{1}	3196 ± 206^{1}	3315 ± 225^{1}
IV	3366 ± 296^{1}	3505 ± 498^{1,2}	3536 ± 542^{1}	3640 ± 523^{1}
		Blood Volume, ml		
I	5511 ± 481^{3,4}	4938 ± 582^{3,4,a}	4933 ± 782^{3,4}	5081 ± 699^{2,3,4}
II	6453 ± 1764^{1}	5465 ± 794^{1,a}	5718 ± 989^{1,a}	6172 ± 1462^{1}
III	6341 ± 544^{1}	5670 ± 417^{1}	5670 ± 449^{1}	5827 ± 498^{1}
IV	6055 ± 470^{1}	6113 ± 754^{1}	6054 ± 791^{1}	6165 ± 745^{1}

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=difference from rehabilitation period; and c=difference between days of experimental period.

Table 14. Extracellular water (Thiocyanate space), kg.[1]

Group	Control	Experimental		Rehabilitation
		Day 4	Day 10	Day 7
I	16.12 ± 2.93	15.05 ± 2.21	16.77 ± 3.86	17.82 ± 3.45
II	16.34 ± 2.90	16.08 ± 3.09	17.26 ± 3.72	16.67 ± 4.74
III	14.78 ± 3.75	16.88 ± 3.58	18.19 ± 2.72	16.24 ± 3.35
IV	16.04 ± 1.77	17.65 ± 3.21	19.02 ± 3.16*	17.59 ± 2.38

1-Mean ± Standard Deviation

*-Significantly different ($P<0.05$) from control - paired t test. See text for discussion of ANOVA.

Table 15. Total body water (deuterium dilution), kg.[1]

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
I	43.67 ± 7.15	43.26 ± 7.24	43.24 ± 6.17	43.06 ± 6.38
II	45.18 ± 5.22	44.31 ± 5.12	43.66 ± 4.79	44.61 ± 4.94
III	48.32 ± 3.52	47.00 ± 3.84	46.50 ± 4.09	46.60 ± 3.63
IV	47.91 ± 4.65	47.92 ± 3.60	47.74 ± 4.95	47.61 ± 4.90

1-Mean ± Standard Deviation

Table 16. Total body water (deuterium dilution) expressed as percent of body weight.

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
I	61.39	62.60	63.38	61.35
II	61.99	62.36	61.95	61.98
III	60.87	60.59	60.65	60.43
IV	67.46	67.16	66.91	66.91

Table 17. Body fat, protein, mineral, and water compartments derived from densitometry.[1]

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
Body Fat, kg				
I	13.00 ± 9.93	12.81 ± 10.02	11.36 ± 9.69	10.60 ± 9.42
II	12.56 ± 4.79^{3}	11.64 ± 4.34^{3}	10.23 ± 4.45^{3}	9.96 ± 4.06^{3}
III	18.02 ± 5.00^{2,4}	17.44 ± 5.55^{2,4}	15.63 ± 4.41^{2}	16.36 ± 4.64^{2,4}
IV	13.00 ± 4.52^{3}	11.51 ± 4.19^{3}	11.53 ± 4.37	11.37 ± 4.09^{3}
Total Body Protein, kg				
I	11.70 ± 1.97	11.37 ± 1.85	11.48 ± 1.84	12.05 ± 1.94
II	12.11 ± 1.33	12.10 ± 1.23	12.17 ± 1.40	12.57 ± 1.36
III	12.39 ± 0.95	12.13 ± 0.97	12.27 ± 0.86	12.20 ± 0.91
IV	11.90 ± 1.29	12.28 ± 1.33	12.26 ± 1.17	12.26 ± 1.22
Body Minerals, kg				
I	3.91 ± 0.68	3.83 ± 0.62	3.87 ± 0.62	4.06 ± 0.65
II	4.04 ± 0.42	4.06 ± 0.41	4.09 ± 0.47	4.29 ± 0.38
III	4.17 ± 0.32	4.08 ± 0.33	4.14 ± 0.30	4.13 ± 0.31
IV	3.94 ± 0.43	4.06 ± 0.44	4.06 ± 0.39	4.06 ± 0.40
Total Body Water, kg				
I	42.30 ± 7.12	41.09 ± 6.68	41.50 ± 6.63	43.55 ± 7.00
II	44.02 ± 4.59	43.56 ± 4.43	43.97 ± 5.04	45.45 ± 4.92
III	44.79 ± 3.44	43.86 ± 3.53	44.52 ± 3.17	44.35 ± 3.38
IV	42.35 ± 4.60	43.71 ± 4.73	43.66 ± 4.17	43.64 ± 4.33

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=GP III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control: b=different from rehabilitation period; and c=difference between days of experimental period.

Table 18. Lean body mass derived from densitometry and total body water derived from densitometry expressed as percent of body weight.[1]

Group	Periods: Control	Periods: Experimental, Day 4	Periods: Experimental, Day 10	Periods: Rehabilitation, Day 7
		Lean body mass, kg		
I	57.94 ± 9.75	56.29 ± 9.15	56.85 ± 9.09	59.65 ± 9.59
II	60.30 ± 6.29	60.11 ± 5.61	60.25 ± 6.91	62.26 ± 6.74
III	61.36 ± 4.71	60.13 ± 4.85	60.99 ± 4.34	60.75 ± 4.63
IV	58.02 ± 6.31	59.83 ± 6.46	59.81 ± 5.71	59.78 ± 5.93
		Lean body mass, % of body weight		
I	82.7 ± 6.8	82.3 ± 7.3	84.8 ± 7.1	86.3 ± 7.0[3]
II	82.9 ± 5.2[2]	84.9 ± 6.0[3]	85.6 ± 5.3[3]	86.7 ± 5.0[3]
III	77.4 ± 5.2[2]	77.6 ± 6.6[2,4]	79.6 ± 5.2[2]	78.8 ± 5.7[1,2,4]
IV	81.9 ± 4.7	84.1 ± 4.5[3]	84.1 ± 4.6	84.3 ± 4.4[3]
		Total body water, % of body weight		
I	60.4 ± 4.9	60.5 ± 5.3	61.9 ± 5.2	63.0 ± 5.1[3]
II	60.5 ± 3.8[3]	61.4 ± 3.3[3]	62.5 ± 3.9[3]	63.3 ± 3.7[3]
III	56.5 ± 4.2[2]	56.6 ± 4.7[2,4]	58.1 ± 3.8[2]	57.5 ± 4.1[1,2,4]
IV	59.8 ± 3.4	61.4 ± 3.4[3]	61.4 ± 3.3	61.5 ± 3.2[3]

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I: 2=Gp II: 3=Gp III: and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control: b=different from rehabilitation period: and c=difference between days of experimental period.

Table 19. Skin fold thickness (mm) of triceps and scapula.[1]

Group	Control	Experimental Day 10	Rehabilitation Day 7
		Triceps - right	
I	8.7 ± 4.6	9.0 ± 4.1	8.4 ± 4.7
II	7.5 ± 2.5	8.2 ± 3.1	7.9 ± 2.6
III	11.3 ± 4.4	11.3 ± 4.8	10.9 ± 3.9
IV	8.6 ± 2.2	9.1 ± 2.4	8.7 ± 2.9
		Triceps - left	
I	8.2 ± 5.6	9.6 ± 5.8	8.1 ± 4.7
II	8.0 ± 3.0^{3}	7.4 ± 2.3^{3}	7.7 ± 2.7
III	11.6 ± 4.8^{2}	11.0 ± 4.7^{2}	11.0 ± 4.4
IV	3.2 ± 2.1	8.4 ± 2.3	8.6 ± 2.5
		Scapula - right	
I	9.7 ± 5.7	9.8 ± 5.8	9.9 ± 5.4
II	9.3 ± 3.5	10.1 ± 3.6	9.9 ± 3.4
III	13.2 ± 4.7	13.0 ± 4.0	12.6 ± 3.4
IV	9.7 ± 4.4	10.8 ± 3.9	10.7 ± 4.0
		Scapula - left	
I	10.5 ± 6.3	10.5 ± 6.0	9.7 ± 5.1
II	10.1 ± 3.9	9.9 ± 4.1	9.8 ± 3.6
III	13.3 ± 3.8	13.1 ± 4.3	11.7 ± 3.4
IV	10.1 ± 4.1	10.2 ± 3.6	10.1 ± 3.3

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 20. Circumferences of biceps, xiphoid, waist and buttocks.[1]

Group	Control	Experimental Day 4	Experimental Day 10	Rehabilitation Day 7
		Biceps, right, cm		
I	28.7 ± 3.2	29.6 ± 4.2	29.2 ± 3.9	29.3 ± 3.6
II	29.2 ± 1.9	28.8 ± 2.0[3]	28.7 ± 2.2	28.9 ± 1.8
III	30.9 ± 1.5	31.3 ± 1.4[2]	29.9 ± 1.2	29.8 ± 1.3
IV	29.0 ± 2.3	29.5 ± 2.5	29.2 ± 2.7	29.1 ± 2.9
		Biceps, left, cm		
I	28.1 ± 4.0	29.4 ± 3.5	28.9 ± 3.5	28.7 ± 3.3
II	28.9 ± 2.0[3]	28.8 ± 2.2[3]	28.3 ± 2.4[3]	28.7 ± 1.9
III	30.7 ± 1.2[2,4,b]	30.8 ± 0.9[2,4,b]	30.3 ± 0.8[2]	29.3 ± 1.2[a]
IV	28.7 ± 2.3[3]	28.8 ± 2.5[3]	29.0 ± 2.5	28.7 ± 2.7
		Xiphoid, cm		
I	84.1 ± 8.6	84.4 ± 7.8	83.8 ± 8.6	84.9 ± 8.3
II	87.8 ± 6.1	87.8 ± 5.0	86.9 ± 5.3	87.7 ± 5.6
III	91.3 ± 5.4	91.2 ± 5.6	90.8 ± 5.0	89.7 ± 4.9
IV	88.6 ± 7.3	88.3 ± 8.0	87.1 ± 6.3	88.8 ± 8.0
		Waist, cm		
I	78.9 ± 10.7	77.2 ± 10.4	76.0 ± 10.3	77.3 ± 10.9
II	79.5 ± 9.0	78.9 ± 8.0	78.0 ± 7.8	79.4 ± 6.7
III	86.1 ± 4.3[4]	83.7 ± 4.7	83.6 ± 3.8[4]	83.0 ± 3.2[4]
IV	78.8 ± 8.6[3]	78.7 ± 8.9	77.0 ± 6.6[3]	77.6 ± 6.0[3]

Table 20. Circumferences of biceps, xiphoid, waist and buttocks.[1] (Continued)

Group	Periods			
	Control	Experimental		Rehabilitation
		Day 4	Day 10	Day 7
		Buttocks, cm		
I	94.2 ± 9.9	93.6 ± 9.7	92.7 ± 8.8	94.0 ± 8.9
II	95.0 ± 4.0^{3}	93.9 ± 4.4^{3}	94.0 ± 4.2^{3}	94.8 ± 4.1^{3}
III	99.3 ± $1.7^{2,4}$	97.9 ± 1.8^{2}	97.5 ± 1.8^{2}	97.7 ± 1.5^{2}
IV	92.4 ± 8.1^{3}	93.0 ± 8.9	93.9 ± 5.3	94.9 ± 5.3

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 21. Summary of skin folds and anthropometric changes at the end of the experimental period expressed as a percentage of the control value.

Measurement	Groups			
	I	II	III	IV
Triceps, R	+ 3.4	+ 9.3	0	+ 5.8
Tricepts, L	+17.1	- 7.5	- 5.2	+ 2.4
Scapula, R	0	+ 8.6	- 1.5	+11.3
Scapula, L	0	- 2.0	- 1.5	+ 1.0
Biceps, R	+ 1.8	- 1.7	- 3.2	+ 0.7
Biceps, L	+ 2.8	- 2.1	- 1.3	+ 1.0
Xiphoid	- 0.4	- 1.0	- 0.5	- 1.7
Waist	- 3.7	- 1.9	- 2.9	- 2.3
Buttocks	- 1.6	- 1.1	- 1.8	+ 1.6

Table 22. Pulmonary function as measured by MBC, MBC frequency, vital capacity and residual volume.[1]

Group	Periods: Control	Experimental: Day 4	Experimental: Day 10	Rehabilitation: Day 7
		MBC, liter/min		
I	$152 \pm 18^{2,3,4}$	$161 \pm 19^{3,4}$	165 ± 20^{3}	$162 \pm 24^{3,4}$
II	176 ± 26^{1}	176 ± 33	173 ± 34	186 ± 28
III	188 ± 20^{1}	190 ± 13^{1}	194 ± 18^{1}	192 ± 16^{1}
IV	193 ± 22^{1}	194 ± 12^{1}	185 ± 24	198 ± 24^{1}
		MBC frequency, R/min		
I	114 ± 14^{4}	$111 \pm 18^{3,4}$	121 ± 22^{2}	$118 \pm 21^{3,4}$
II	107 ± 20^{4}	$105 \pm 21^{3,4}$	$97 \pm 14^{1,3,4}$	$110 \pm 22^{3,4}$
III	$127 \pm 16^{4,b}$	$136 \pm 24^{1,2}$	144 ± 37^{2}	$154 \pm 26^{1,2,a}$
IV	$151 \pm 29^{1,2,3}$	$144 \pm 29^{1,2}$	147 ± 35^{2}	$158 \pm 32^{1,2}$
		Vital Capacity, liters		
I	$3.98 \pm 0.65^{2,3,4}$	$3.94 \pm 0.66^{2,3,4}$	$3.99 \pm 0.74^{2,3,4}$	$3.94 \pm 0.75^{2,4}$
II	4.93 ± 0.87^{1}	4.83 ± 0.86^{1}	4.92 ± 0.86^{1}	4.87 ± 0.93^{1}
III	4.76 ± 0.58^{1}	4.81 ± 0.47^{1}	4.67 ± 0.46^{1}	4.58 ± 0.46
IV	4.75 ± 0.52^{1}	4.74 ± 0.51^{1}	4.68 ± 0.56^{1}	4.68 ± 0.53^{1}
		Residual Volume (N_2), liters		
I	1.44 ± 0.42	1.41 ± 0.31	1.54 ± 0.41	1.67 ± 0.42^{2}
II	1.24 ± 0.27	1.29 ± 0.30	1.23 ± 0.27	1.22 ± 0.26^{1}
III	1.36 ± 0.35	1.36 ± 0.36	1.36 ± 0.36	1.33 ± 0.30
IV	1.33 ± 0.36	1.33 ± 0.36	1.33 ± 0.32	1.38 ± 0.35

1-Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control; b=different from rehabilitation period; and c=difference between days of experimental period.

Table 23. Pulmonary functions as measured by ERV, inspiratory capacity, total lung capacity and RV/TC ratio.[1]

Group	Periods: Control	Experimental: Day 4	Experimental: Day 10	Rehabilitation: Day 7
		ERV, liters		
I	1.34 ± 0.35	1.35 ± 0.39	1.40 ± 0.44^{2}	1.26 ± 0.36^{2,4}
II	1.63 ± 0.32	1.84 ± 0.32^{3}	1.84 ± 0.44^{1}	1.65 ± 0.34^{1}
III	1.31 ± 0.36	1.41 ± 0.37^{2}	1.48 ± 0.41	1.31 ± 0.33^{4}
IV	1.72 ± 0.45	1.65 ± 0.39	1.64 ± 0.40	1.68 ± 0.36^{1,3}
		Inspiratory Capacity, liters		
I	2.64 ± 0.50^{3,4}	2.58 ± 0.53^{3,4}	2.61 ± 0.53^{2,3,4}	2.67 ± 0.57^{2,3}
II	3.26 ± 0.66	2.99 ± 0.58	3.11 ± 0.54^{1}	3.27 ± 0.66^{1}
III	3.45 ± 0.45^{1}	3.35 ± 0.42^{1}	3.23 ± 0.49^{1}	3.31 ± 0.36^{1}
IV	3.14 ± 0.28^{1}	3.17 ± 0.26^{1}	3.14 ± 0.36^{1}	3.05 ± 0.36
		Total Lung Capacity, liters		
I	5.42 ± 0.97	5.31 ± 0.97^{4}	5.55 ± 1.09	5.60 ± 0.96
II	6.15 ± 0.91	6.12 ± 0.88	6.18 ± 0.95	6.14 ± 0.91
III	6.09 ± 0.61	6.13 ± 0.54	6.07 ± 0.51	5.97 ± 0.49
IV	6.18 ± 0.68	6.15 ± 0.72^{1}	6.14 ± 0.65	6.12 ± 0.66
		RV/TC, %		
I	26.6 ± 4.1^{2,4}	25.9 ± 2.9	27.4 ± 3.2^{2,3,4}	28.0 ± 4.6^{2,3,4}
II	20.5 ± 4.1^{1}	21.3 ± 5.0	20.1 ± 4.4^{1}	20.2 ± 4.5^{1}
III	22.4 ± 5.2	22.1 ± 5.2	22.4 ± 5.3^{1}	22.2 ± 4.5^{1}
IV	22.3 ± 3.9^{1}	22.2 ± 3.8	22.3 ± 3.7^{1}	22.4 ± 4.5^{1}

1–Mean ± Standard Deviation

Between Groups. Superscript denotes significant difference ($P<0.05$) from number of group in superscript. Superscript number 1=Group I; 2=Gp II; 3=Gp III; and 4=Gp IV.

Within group differences significant at $P<0.05$ are superscript: a=different from control b=different from rehabilitation period; and c=difference between days of experimental period.

Table 24. Pulmonary function, percentage changes during the experimental period.

Parameter	Groups			
	I	II	III	IV
MBC	+ 8.6	- 1.7	+ 3.2	- 4.1
MBC, frequency	+ 6.1	- 9.3	+13.4	- 2.6
Vital Capacity	+ 0.2	- 0.2	- 1.9	- 1.5
Residual Volume	+ 6.9	- 0.8	0	0
ERV	+ 4.5	+12.9	+13.1	- 4.6
Inspiratory Capacity	- 1.1	- 4.6	- 6.4	0
Total Lung Vol.	+ 2.4	+ 0.5	- 0.2	- 0.6
RV/TC	+ 3.0	- 2.0	0	0

Table 25. Oxygen consumption in liters per minute and milliliters per min per kilogram of body weight during maximum work.

Group	Periods: Control	Experimental: Day 3	Experimental: Day 9	Rehabilitation: Day 5
	Liters/minute			
I	3.08 ± 0.68	2.74* ± 0.37	2.74* ± 0.41	2.78* ± 0.53
II	3.14 ± 0.36	3.01 ± 0.34	3.30 ± 0.34	3.20 ± 0.42
III	3.37 ± 0.39	3.20 ± 0.37	3.12* ± 0.33	3.23 ± 0.22
IV	3.03 ± 0.22	3.01 ± 0.42	2.97 ± 0.29	2.96 ± 0.36
	ml/kg/min			
I	43.6 ± 7.3	40.4 ± 5.7	40.8 ± 5.3	40.2* ± 5.8
II	43.7 ± 6.1	42.9 ± 3.6	43.2 ± 3.1	45.2 ± 2.7
III	42.8 ± 5.7	41.1 ± 5.6	40.9* ± 4.7	41.9 ± 3.4
IV	42.6 ± 4.3	42.2 ± 5.2	42.0 ± 4.2	41.6 ± 4.2

1-Mean ± Standard Deviation

*Significantly different from controls using ANOVA at $P<.05$.

ELECTROENCEPHALOGRAM INTERPRETATIONS

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APPENDIX C

APPENDIX C

Electroencephalogram Interpretations

Subject 1

1. Date - 9 Sep 68 - Control.

Interpretation: Basic frequency 10 per second. Alpha well developed. No focus or asymmetry. Sleep spindles present and symmetrical. No abnormalities on photic stimulation.

Impression: Normal record.

2. Date - 23 Sep 68 - Restriction phase.

Interpretation: Basic frequency 10-12 per second. No asymmetry. No focus. No pathological buildup on hyperventilation. Normal sleep. Normal driving on photic stimulation. Normal Record.

Impression: Normal record.

Subject 2

1. Date - 10 Sep 68 - Control.

Interpretation: Basic frequency 8-10 per second. Alpha well developed. No focus. No asymmetry. No buildup on hyperventilation. No changes on photic stimulation.

Impression: Normal record.

2. Date - 23 Sep 68 - Restriction phase.

Interpretation: Basic frequency 8-10 per second. No focus. No asymmetry. There is slight buildup on hyperventilation which is not sustained.

Impression: Normal awake record.

Subject 3

1. Date - 11 Sep 68 - Control.

Interpretation: Basic frequency 8-10 per second. There is one run of 3-4 per second slowing in the left frontal

temporal lead which was not repeated. On hyperventilation alpha became disorganized and is sustained for one minute. Sleep record normal.

Impression: Slightly abnormal record with possible left frontal temporal slowing.

2. Date - 25 Sep 68 - Restriction phase.

Interpretation: Basic frequency 8-10 per second. It is difficult to read the type of runs as writing is illegible but there appears to be some 3-6 per second slowing over the left frontal temporal area in sleep. There is buildup on hyperventilation but it is not as prominent as in previous record nor is it sustained. Normal photic stimulation.

Impression: Probably abnormal slow record with left hemisphere slowing.

Subject 4

1. Date - 11 Sep 68 - Control.

Interpretation: Basic frequency 9-11 per second. No focus. No asymmetry. There is paroxysmal buildup on hyperventilation of 4-6 per second SLOW waves which persist for 1 ½ minutes. No change on photic stimulation.

Impression: Slightly abnormal, non-focal, slow record.

2. Date - 24 Sep 68 - Restriction phase.

Intrepretation: Basic frequency 8-10 per second. No focus. No asymmetry. There is paroxysmal buildup on hyperventilation which is sustained for 10-15 seconds. Normal photic stimulation.

Impression: Borderline, normal record. Not as much buildup as on previous record.

Subject 5

1. Date - 12 Sep 68 - Control.

Interpretation: Basic frequency 8-10 per second. No dysrhythmia. No asymmetry, no seizure discharge, no driving on photic stimulation. Normal hyperventilation response.

Impression: Normal record.

2. Date - 25 Sep 68 - Restriction phase.

Interpretation: Basic frequency 9-11 per second. No dysrhythmia or asymmetry. Normal hyperventilation response. No seizure discharge. No driving on photic stimulation.

Impression: Normal awake, sleep and photic stimulation record.

Subject 6

1. Date - 9 Sep 68 - Control.

Interpretation: Basic frequency 8-10 per second. No focus. No asymmetry. There is some sharp activity in the parietal leads both on hyperventilation and on photic stimulation. Alpha is poorly developed for age.

Impression: Borderline, abnormal, sharp record.

2. Date - 23 Sep 68 - Restriction phase.

Interpretation: Basic freauency 8-9 per second. Alpha slightly better developed than previous record. No buildup on hyperventilation which is pathologically sustained. No driving on hyperventilation.

Impression: Normal awake record.

Subject 7

1. Date - 12 Sep 68 - Control.

Interpretation: Basic 8-10 per second. Alpha well-developed. No focus. No asymmetry. No sleep record. Normal photic stimulation.

Impression: Normal record.

2. Date - 24 Sep 68 - Restriction phase.

Interpretation: Basic frequency 8-10 per second. Alpha well-developed. No focus. No asymmetry. Sleep record normal.

Immpression: Normal awake and sleep record.

Subject 9

1. Date - 13 Sep 68 - Control.

Interpretation: Basic frequency 8-10 per second. No focus. No asymmetry. There is a marked paroxysmal buildup on hyperventilation with high voltage, 3 per second waves in maily parietal and fronal leads. This is sustained for about 2 minutes. In sleep there are occasional pariental lunges and sleep spindles. However, there is not focus or asymmetry.

Impression: Abnormal, paroxysmal, non-focal, slow record.

2. Date - 25 Sep 68 - Restriction phase.

Interpretation: Basic frequency 8-10 per second. No focus. No asymmetry. There is paroxysmal buildup on hyperventilation with 4-6 per second activity which is not sustained. There is one paroxysm of sharp activity in a drowsy period of short duration.

Impression: Borderline, normal record - because of paroxysm in sleep. Much better than in previous record.

Subject 10

1. Date - 13 Sep 68 - Control.

Interpretation: Basic frequency 8-9 per second. There is much muscle artifact in the record. No focus. No asymmetry. Short, drowsy period was normal. No pathological buildup on hyperventilation.

Impression: Normal awake period.

2. Date - 25 Sep 68 - Restriction phase.

Interpretation: Basic frequency 10-11 per second. No focus. No asymmetry. Alpha of lower voltage than in previous record. No buildup on hyperventilation. Normal photic stimulation record.

Impression: Normal awake and drowsy record.

Subject 12

1. Date - 10 Sep 68 - Control.

Interpretation: Basic frequency 8-9 per second. Alpha at times sharp. On hyperventilation, there is much disintegration of alpha which is sustained for 20-30 seconds. Though borderline, slightly better than later record.

Impression: Borderline record.

2. Date - 24 Sep 68 - Restriction phase.

Interpretation: Basic frequency 8-11 per second. Excess buildup on hyperventilation which was sustained less than 20 seconds. There was some sharp activity in sleep which is asymmetrical. As whole - record not well developed. Sharp activity was in sleep. Even considering the age of patient record poorly developed.

Impression: Borderline tracing.

NOTE: Electroencephalograms and initial interpretations were obtained at the Electroencephalography Laboratory, Section of Neurology, Gorgas General Hospital, ANCON, Canal Zone, Panama. The above interpretations were provided by Colonel Eugene W. Eberlin, C, Neurology Service, Brooke Army Medical Center, Ft. Sam Houston, Texas.

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